

Metallurgical & Chemical Engineering

Volume XV,

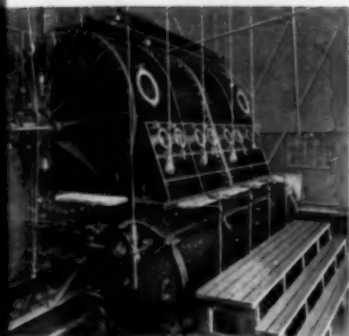
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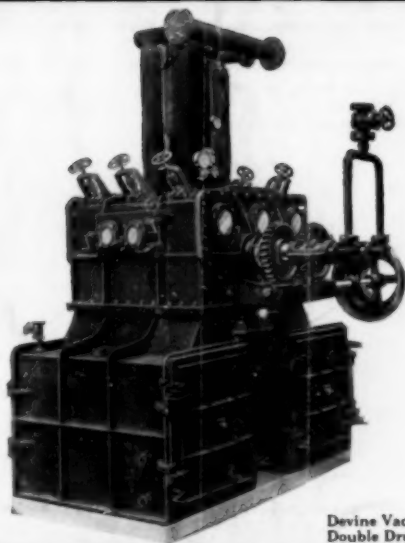
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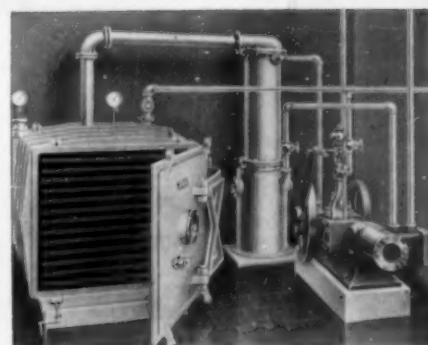
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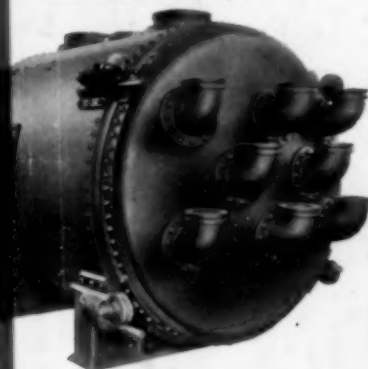
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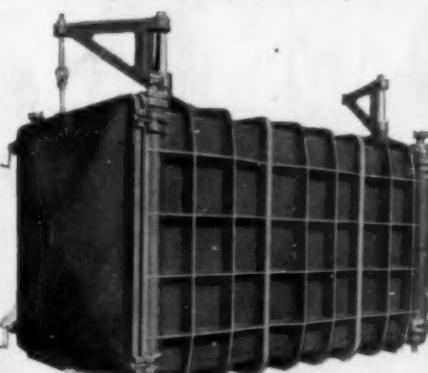
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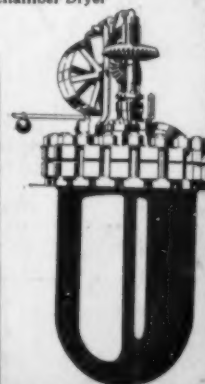
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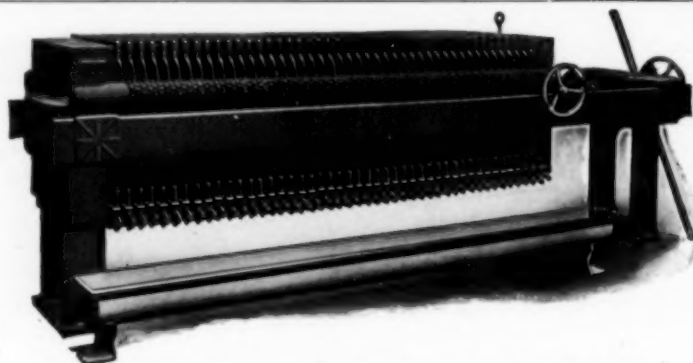
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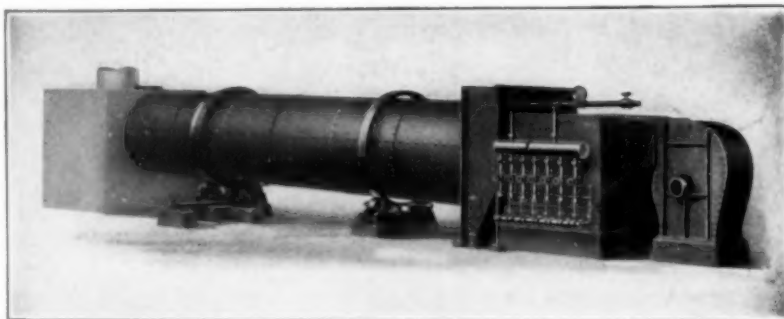
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The New Phase in the Dyestuff Tariff Fight before Congress

A new dyestuff tariff bill has been placed before Congress, together with the general revenue bill of the Administration. The dyestuff tariff fight has thereby entered into a decidedly new phase.

That almost certainly a new dyestuff tariff will be enacted by the present Congress means two very important things. First, that everybody in Congress agrees that it is a vital necessity for the American nation to be self-contained with respect to the dyestuff and allied industries. Second, that everybody in Congress now agrees (and this has never happened before) that the creation and the sound development of a general dyestuff industry is impossible without a protective tariff sufficiently high to give real protection and not merely yield revenue.

This is, in fact, a big achievement and full credit must be given to the Administration and to Congress for having agreed on the principle. It is clear proof of an earnest desire of the Administration and of Congress to deal with the chemical industries with that degree of fairness of consideration to which the chemical industries are entitled in view of their fundamental importance for the nation, but which has not always been accorded them in the past.

As an agreement has now been reached on the principle, it should not be difficult to discuss the remaining differences intelligently without excitement. The present situation may be summed up as follows: All agree that the present Underwood tariff is insufficient. But the representatives of the chemical industries insist that the rates of the Hill tariff bill represent the minimum necessary for real protection, while the Kitchen tariff bill now before Congress grants less.

One decidedly novel feature of the Kitchen bill (which is given in detail on page 65 of this issue) is that it sets a time limit on the surtax. As it is an infant industry that is to be protected no one can object to the fairness of the principle of the time limit. The question of how long a new industry is an infant and needs protection, remains open. But as this is a matter which can be adjusted or corrected in the future, we may dismiss this fundamentally most interesting feature of the Kitchen bill from our present discussion.

There remain two important differences between the Kitchen bill and the Hill bill and these deserve immediate attention. The first relates to the amount of protection. As the detailed differences between the rates of the Underwood, Kitchen and Hill bills are given on page 65, it will be best here to bring out these differences by another rather instructive method for which

we are indebted to Dr. B. C. Hesse, one of the foremost authorities on the subject. Dr. Hesse bases his discussion on the amount of importations of dyestuffs and intermediates into this country in 1913. The duty on these according to the Underwood tariff is \$2,298,632, while it would be \$4,999,084 for the Kitchin bill, and \$6,908,648 for the Hill bill. In other words, where Underwood grants \$1.00 protection, Kitchin proposes a protection of \$2.18, Hill of \$3.00. (Of course, with a different proportion of the importations of aniline dyes, of alizarine and anthrazene dyes and indigo, and of intermediates, the proportion indicating the relative protection afforded by the Underwood, Kitchin and Hill tariffs respectively would be somewhat different from 1 to 2.18 to 3, but these are the best figures available.)

Now what does this really mean? This country wants to add a new industry to its national household. Is it wise to haggle and try to do for \$2.18 what all experts agree costs \$3.00 if it is to be done right? If an individual house owner wants an addition made to his house and on expert advice finds it will cost him \$3,000 to have it done right, he would certainly hesitate a long time before trying to find somebody who would agree to do something for \$2,180. If he is wise he will decide to have it done for \$3,000 if it is to be done at all. Can the American nation afford to be less judicious if it really wants an American dyestuff industry?

The second important difference is that the Hill bill tries to protect the industry all around, the Kitchin bill does not, as it exempts alizarin and anthracene dyes and indigo from the surtax. We cannot do better than quote Dr. B. C. Hesse's comment on this feature: "If you were building a high board fence around your vegetable garden to keep your neighbor's chickens out would you build three-fourths of the fence so that it went well into the ground, and leave the other one-fourth 3 ft. from the ground on the theory that the chickens would not find this weak spot in your fence? In exempting anthracene, alizarin and indigo dyes and indigo from the surtax, that is precisely the theory on which the Kitchin bill proceeds, and it offers, at the suspended portion of the fence an added bait for the chickens, by threatening to remove the surtax unless 60 per cent of the value of our total consumption is produced in this country within five years. This is about the same as if, in addition to building the fence as just described, you industriously sprinkled a lot of 'chicken feed' so that it leads directly to this hole in your fence. This is the strategy of the Kitchin bill."

A wonderful beginning has been made by American dyestuff manufacturers during the past few years. To accomplish more—to accomplish all that this nation has a right to wish for—they now need the support of the nation as represented by Congress. And Congress has made a wonderful beginning by grasping correctly the principal point of the situation.

Having shown a broad attitude of mind in the matter of principle, Congress can hardly afford to spoil its work by narrowness in fundamentally important details. We sincerely hope that the provisions of the Hill bill will be enacted into law.

Increased By-Product Coking

No criticism can be made of the rate at which the iron industry is now adopting the by-product coking process. In the earlier years the progress was slow. It was not until 1900 that an output of a million tons of by-product coke was attained and ten years later the output was only 7,138,734 tons. Last year the output was 14,072,895 tons, representing a doubling in five years, a fairly good record, but not a very good one, considering the great promises of profit. In the earlier years, however, the iron industry had to finance its by-product oven construction largely out of profits, and frequently these were not large.

Of late financial machinery has been available whereby such new construction could be much more readily undertaken.

With an output during last year of 14,000,000 tons, the capacity available at the close of the year may be estimated at considerably more. Several batteries of ovens have since been completed and much construction work is in progress, the present program indicating that new plants, of from say 50 to 200 ovens, are to be completed at an average of about two per month during the next six or nine months. The by-product coking capacity a twelvemonth hence will probably be close to 25,000,000 tons, representing between 40 and 45 per cent of the prospective coke requirements of the country, which may be estimated at not far from 55,000,000 tons.

Necessarily a great many beehive ovens must be abandoned, for the increase in the production of by-product coke is very greatly in excess of the increase in consumptive requirements. The production of beehive coke, indeed, reached its maximum as long ago as in 1907, and the decreases since then have not been due entirely to ovens being abandoned because the coal over which they had been located was worked out. The condition of forced abandonment of beehive ovens makes it that the coal remaining becomes available and there is less search for new and cheap coal for by-product use than was expected. Connellsville and Pocahontas coals are already being shipped in a large way to by-product ovens. In many instances, indeed, the by-product ovens are built by furnace interests having beehive coking operations, the beehive ovens being simply abandoned and the coal shipped to the new ovens, to be used perhaps in conjunction with smaller proportions of coal from other districts.

By far the major part of the by-product coking now being done or in prospect involves the recovery of little of the by-products apart from the gas, and it is evident that when by far the major part of the coke is being made by the by-product process there will still be a great deal of work to be done by way of installing the adjunct processes for various recoveries of the other valuable products.

Dirty Oils

Oils are delicate bodies, complex in composition, and those of vegetable or animal origin are very likely to decay if they are not properly treated. It is not con-

sidered good form to let a dead pig lie around until it becomes a nuisance and then proceed to secure the lard from it. But many oils which are as complex in their constitution and as subject to decay as lard are handled in such a manner that no plant or animal could live and contain them in the condition that they are brought upon the market. It is safe to say that millions of dollars are annually lost in the United States on oils that were originally good and that could have been kept good, but have gone bad. Oils should be refined as soon as possible after they are pressed because organic oils have a way of increasing like rabbits, once they get started, and while the cottonseed oil industry, with its problems of transportation and the signal chemical talent engaged in it may well be allowed to take care of its affairs without gratuitous criticism, there are other oils that come to market in a condition that calls for a little investigation as to their sources and then a little admonition and wholesome advice to their producers.

The tropics sometimes seem hopeless. Some presses lately sent down and set up at a convenient tropical station were not operated on the ground that they were too heavy for women and children to work them. A little civilization is creeping in and it occasionally shows in the oils; but civilization grows delicate when it reaches the tropics and care must be taken that it does not grow thin from loss of temper.

Peanut oil, coming from France, is much better prepared than any domestic product—or at all events the most of our domestic product—and there is no reason for this at all. When peanuts are pressed in their husks, in an old cottonseed press that has not been cleaned out, it indicates a looseness of method that should be corrected. There's no use in letting things get down at the heel that way. When we consider what careful treatment oils need the time seems ripe for calling for better factory practice in their preparation. A great deal of trouble will be avoided if more attention is paid to this first step in the industry.

Blast Furnace Performance

The blast furnaces of the United States have disclosed quite accurately in the past six months what they can do. There have been only minor variations in the rate of output, and these are attributable largely to weather conditions. There were increases in February and March and a further increase in May, while production fell off a trifle in June. The performance seems to have been quite in line with conditions as to humidity in the atmosphere, and as both the steel interests and the merchant furnaces have been striving for maximum output the actual production seems to be an accurate index to the average commercial capacity. This may be taken at an average of 39,500,000 to 40,000,000 tons for a twelvemonth, with its periodic variations in weather conditions.

It is commonly said in the iron industry that after a period of relative inactivity the furnaces are found to be in good physical condition, all nicely relined, etc.,

whereby they can stand a strong campaign for a time, but that after such a campaign so many must go out for relining that the production is then reduced. There has been no case in actual practice of this theory being substantiated. Production declines only when the weather becomes unfavorable or the demand for iron decreases, and sometimes in the latter case it does not decrease altogether as promptly as it should. There is no reason to believe that the existing furnaces could not make close to 40,000,000 tons of pig iron in the twelve-month from date.

One new blast furnace was completed and blown in May 13 and another on June 5, while nine stacks are now in course of construction, their average date of completion being perhaps about six months hence, while all the new stacks should be completed within a twelve-month, if market conditions continue such that rapid construction work is desirable. The country's commercial capacity may then be taken at about 41,500,000 tons a year.

Only a qualified statement as to capacity, however, can be made, as commercial conditions vary. At the present time an unusually large amount of spiegeleisen and ferromanganese is being made, the tonnage output being counted simply as "pig iron," whereas the output per stack is much less than if real pig iron were being made. One does not know whether the furnaces will make more or less of the manganese alloys in future, that being a matter of commerce, not of physical capacity.

Again, in the whole history of the blast-furnace industry there have been furnaces falling by the wayside. They are not kept up to date physically, or conditions change as to supplies of raw material. They are not abandoned immediately upon their last blast, as the owners are disposed to wait for something to turn up. Under exceptional market conditions, with high-priced pig iron and relatively low-priced raw materials a furnace supposedly out of the running may become active, while in reverse conditions a furnace supposedly fit may have to be counted out. Thus the commercial capacity of the country really varies by a complicated formula, in which there are factors of demand, market prices of pig iron and raw materials, wage rates and other items. What is called "demand" is a separate factor, for there have been times when the going market price appeared sufficient to bring an idle stack into blast, but it was impossible to sell sufficient tonnage at the price to justify incurring the lump sum expense of blowing in the stack. Thus one can hardly say more than that under present commercial conditions the actual blast furnace capacity is in the neighborhood of 39,500,000 to 40,000,000 tons, and is destined to become 41,000,000 to 42,000,000 tons within a twelve-month. The existing capacity proves to be larger by several million tons than was estimated before the furnaces were subjected to their present test. As a rule the individual outputs have exceeded previous outputs and sometimes they have surprised the managers themselves.

Readers' Views and Comments

Liquid Jets

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of June 15 I read with interest the comments of Mr. B. DuFaur upon the article of Mr. C. Terry Durell regarding liquid jets, which appeared in your issue of March 1 last.

Mr. DuFaur states that the liquid jet was used in Australia as early as 1908. It is quite well known that it was used in America some years before that time for the purpose of efficiently commingling a liquid and gas under pressure.

During the year 1903 I used the liquid jet as a fume arrester. The entire arrangement consisted of a 2-in. centrifugal pump, a small tank, a nozzle and its housing, and the necessary piping to connect all into a continuous circuit. The nozzle with its housing appeared as a very large filter pump and patterned after the one commonly used in the laboratory.

When the entire arrangement was to be placed in operation, the tank was filled with the liquid and the centrifugal pump started, it being supplied by the liquid in the tank. The liquid was thus forced by the pump through the nozzle and then delivered to the tank with its burden of commingled gas. The liquid was then taken up by the centrifugal pump again, and thus continuously circulated.

About the time mentioned above or shortly thereafter I applied for a U. S. patent covering the arrangement as a fume arrester. The patent was allowed but I never took it out. I learned through the patent office that practically the same thing had been patented some years before for the purpose of purifying illuminating gas.

During the year 1905 I conducted experiments upon a much larger scale at the property of a mining and smelting company of Utah. In these experiments I used a 10-in. centrifugal pump but the cost of pumping was excessive. Under the most favorable conditions the amount of free cold gas drawn into my apparatus approached one volume for every volume of liquid passed through the nozzle.

This method was used by me quite frequently to aerate cyanide solutions, and during the last few years I have made numerous flotation experiments by use of the method with varying degrees of success.

HENRY R. ELLIS.

Salt Lake City, Utah.

Buttering Wages

To the Editor of Metallurgical & Chemical Engineering

Sir:—Far be it from me to urge the love of money upon people. The general impression prevails that we have enough of that sort of thing in this country, and I have no desire to contradict it. But when I consider the habits of life that prevail in many places, which are too low to entertain thrift, I begin to doubt the old saw that the love of money is the root of all evil.

There is a great deal of work to be done in this world and most of us need an incentive of some kind to induce us to lend a hand. This applies to all of us: masses, classes, member of manufacturers' associations, boards of trade and the I. W. W. It is also worthy of note that the art of getting work done seems to involve something more than the payment of wages. It appears that wages need to be buttered in some way to make them acceptable, and to neutralize their bad

effects. Let us consider a few examples from fact and fiction in which it is indicated that high wages may fail to pay.

I once had a skilled workman in my employ, in charge of a kettle. The man received \$2 a day. He was a good man, intelligent, industrious and willing. He then received authority over three kettles and two helpers, his pay being increased to \$2.50 a day. In time he achieved supervision over all the kettles; his wages were \$3 a day, and I was relieved of the constant agony of watching the kettles and the fear that some careless laborer might waste several hundred dollars worth of material.

Close at hand was another operation that needed occasional watching. This was a much lighter task, but attention was important. The foreman was sure he could look after it with ease. Subsequent events proved that he could, and for this he received 25 cents more per day, making in all \$3.25. There seemed to be some devilment in that last quarter. The foreman grew pompous and vain, he bullied the men under him until the best ones left, he conceived the idea that he should be made an elder in the church, and he caused so much trouble in the community that he had to be laid off for a while. There was something wrong in that last quarter; the employer lacked wisdom by not buttering it properly.

In a late number of *Punch* there is depicted a washerwoman who tells her mistress that she cannot continue to wash for her because her man has employment and is earning so much that the last week they had been obliged to put some of their earnings in the bank, and if they did not look out they would be compelled to do the same thing again. This is probably taken from fancy, but it is not an impossibility, as we shall see. The psychological problem is simpler in this case; what the woman and the husband lacked was a knowledge and understanding of the art of administering funds.

Now comes a report of Mr. Richard I. Austin, the Federal Reserve Agent of the Philadelphia district, in regard to the business situation with special reference to the attitude of labor. Mr. Austin says:

"There is universal complaint that as wages are increased a large class of wage-earners become less productive, and the failure of industrial plants to make sufficient or reasonable output is preventing the realization of much, if any profit from operations. The attitude of wage-earners is disappointing. Instead of taking advantage of the present wonderful opportunity to make large earnings, they are apparently not netting much more than formerly, when wages were much lower; the cost of living for them, as for others, is much higher, and the whole country is suffering a great economic loss through the failure of our industrial establishments to produce the volume of goods for which there is at present so great a demand."

There we have it. The week's work is cut down to five days and even less, and because labor is scarce the competent members of the force let down in speed and efficiency. Now there is no use in saying that they are a pack of fools, because they are not. The fact is they are started wrong, their leading is bad, and their philosophy is contrary to what the rest of us believe in public welfare. If laborers were to engage in habits of thrift they would be in a position to make better bargains for themselves when times are hard, because

they would not be under the drive of need to take any work at any wages when both are scarce. They still could bargain and show the value of competent workers over the incompetent ones; they could prove their point and get work, because employers are always out for profits, and they want steady hands.

The argument that has won against this is that of collectivism, in which it is held that they who labor are a class by themselves, the competents and incompetents together, and that whatever will injure the owners of the work is of just that measure of advantage to labor. This is not true, because unless labor keeps in form and keyed up to capacity it can neither administer affairs nor work for itself. Capital selects its instruments with care and drops out sloths, incompetents, booze-lifters and dull-wits to shift for themselves. Capital is selective while labor is collective, and while this does not prevent the two from fighting or hinder labor from running capital, it does prevent labor from winning. Without the discipline of efficiency, speed, thrift and independent thinking, those who are weak of will drift over from competence to incompetence, and a gradual degeneration of labor and production takes place. Labor can do nothing with that incubus.

Why, then, have misleading arguments and a false philosophy gained such headway among laborers? It is not because of the stupidity of laborers. It is because the arguments have been presented to them with greater conviction and superior ability than the arguments for industry and thrift which employers claim to preach. The arguments of the employers have been feeble and without enough interest to make them carry. Labor can come into its own, the productiveness of this country can be increased beyond the dreams of to-day, and the feeble of mind, body, and will can be employed at least so that they support themselves, if only labor will avail itself of that wordly wisdom, without which goodness itself is likely to fail. The stupidest thing on earth is to fight windmills. Next in order of stupidity is the cultivation and development of habits of inertia—of laziness. These two things will kill progress anywhere and any time.

I lately read a letter from a man in prison approaching the end of a long sentence at hard labor. "No matter how you feel," he wrote, "You can't get even with the State or with Society, which has turned you down, by shirking work. My companions call me all sorts of a fool for being a willing worker, but I don't mind that because in this very thing lies my only hope. If I let myself get into the condition in which sustained and hard work is impossible to me—and nothing is easier—then I shall be no good when I get out. And I don't want to come back here a little bit. That is the trouble with the bums here; they can't work more than a few days in succession no matter how hard they try. They are sure to come back."

PETER TEN BROECK.

New York City

Coming Meetings and Events

American Institute of Metals and American Foundrymen's Association, Foundrymen's Convention, Cleveland, Sept. 11-16.

American Institute of Mining Engineers, Arizona, Sept. 18-23.

Mining and Metallurgical Society of America, New York Section, New York, Sept. 21.

Second National Exposition of Chemical Industries, New York, Sept. 25-30.

American Chemical Society, New York, Sept. 25-30.

American Electrochemical Society, New York, Sept. 28-30.

American Society for Testing Materials

An account of the first day's meeting, excepting part of the evening program, of the American Society for Testing Materials' meeting held at Atlantic City, June 27 to 30, was given in our issue of July 1.

Following the presidential address on Tuesday evening an exceedingly interesting paper on the "Hardening and Tempering of Eutectoid Carbon Steel and on the Shore Test," by HENRY M. HOWE and ARTHUR G. LEVY, was presented by Professor HOWE. A paper entitled "Experiments on the Plastic Elongation of Wires" was read by A. V. DE FOREST. This paper contained a description of a sensitive apparatus for observing the "creep" or slow stretch of wire under load, and recording the stress deformation diagram on photographic paper. The paper was discussed by Professor HOWE.

The report of Committee D-1 on "Preservative Coatings for Structural Materials" was read by P. H. WALKER, chairman, and a paper on the "Acceptability of Linseed Oil" was read by C. D. HOLLEY. This paper, which was a discussion on the question of "foots" in linseed oil, elicited further discussion from Messrs. G. H. PICKARD and H. A. GARDNER. Mr. PICKARD, who is a member of the linseed oil committee, said that the committee had been working on the question of how much foots was allowable, but that the laboratory in which the work was being done had been destroyed by fire. Mr. GARDNER cited a case in which the moisture in the foots of a high-foots linseed oil had prevented the paint from drying.

The Wednesday morning meeting was devoted to iron and steel. Professor HOWE, who presided, introduced Prof. A. L. VAN HECKE of the University of Louvain, Belgium, who made a few remarks and expressed his pleasure at being able to attend the meeting. Professor VAN HECKE is studying the latest developments in iron and steel in this country.

Four reports were read of committees A-1, A-4, A-5 and A-6, on "Steel" in general, "Heat Treatment," "Corrosion," and "Magnetic Properties," respectively. These reports were read by Messrs. C. D. YOUNG, ALBERT SAUVEUR, S. S. VOORHEES and C. W. BURROWS, respectively.

A paper was presented on "National Standard Specifications and Their Relation to Export Trade," by W. R. WEBSTER.

A paper on "Heat Treatment of Carbon Steel Locomotive Axles," by C. D. YOUNG, brought out considerable discussion as to the advisability of water quenching instead of oil quenching. The paper discussed results obtained with heat treatment of axles, using oil quenching in one case and water quenching in another. The results were favorable to water quenching.

A paper on "Recrystallization as a Factor in the Failure of Boiler Tubes" was presented by A. E. WHITE and H. F. WOOD. This was the result of an extensive and interesting piece of research work and is reserved for publication in a later issue.

Wednesday afternoon was devoted to recreation, and some of the members journeyed to the Northfield Country Club, where a golf tournament among the members of the society was in progress, and some of the sailing enthusiasts enjoyed this form of sport.

The Wednesday evening session was devoted to Tests and Testing. The report of committee E-1 on "Methods of Testing" was read by G. LANZA, chairman. A topical discussion on yield point and proportional limit was presented by J. E. HOWARD, T. D. LYNCH, H. F. MOORE and F. B. SEELY. It was agreed that the term elastic limit was better to use than proportional limit, and that the term yield point was vague and inexact. Curves

were shown of various steels showing a variety of ranges between the proportional limit and yield point, and it was urged that designers specify steel whose load would always fall well below the proportional limit.

Other papers presented were as follows: "An Apparatus for Determining Soil Pressure," by A. T. GOLDBECK and E. B. SMITH; "Endurance and Impact Tests of Metals," by D. J. MCADAM, Jr.; "Constants and Diagrams for Repeated Stress Calculations," by H. F. MOORE and F. B. SEELY; "Methods of Testing the Durability of Pipe Under Corrosion," by F. N. SPELLER. This paper is published in full on page 87 of this issue.

At this session a resolution was passed indorsing legislation to enforce the use of the Centigrade scale in Government publications after 1920. This is the first time the Society has acted on a legislative question.

The Thursday morning session was devoted to ceramics, road materials, and gypsum. The papers consisted mostly of committee reports.

A paper on "Practical Methods for Testing Refractory Fire Brick" was presented by C. E. NESBITT and M. E. BELL. In discussing this paper J. S. UNGER said it showed the importance of tests for bricks. The suggestion that tests be made more severe than actual working conditions in order to accelerate the tests is a radical departure from accepted practice. Failure of bricks is not due to one cause, but to a combination of several causes. Dr. Unger did not think that the rapid water-cooling used in the tests was comparable to air-cooling in practice. The results showed that some bricks are different at one end than at the other, and therefore show a non-uniformity of material. The most important parts of the paper are the curves showing the effect of water in making brick and the table showing the pressure effect. G. C. STONE confirmed the contention that denser brick was the better to use. He found that in testing brick it was impossible to get good slagging results except in actual practice. W. H. FULWEILER said the authors were to be congratulated for having the courage to break away from ordinary testing methods. He thought the results of using a ball as pressure medium against brick might not give the same results as a load spread over the whole brick. In tests made by him the removal of the outer skin caused irregularity in the results. R. C. PURDY said that he had found no laboratory test comparable to service tests. Publication in full of this paper is reserved for a later issue.

A smoker was held Thursday evening, at which a general good time was had.

The Friday morning session was devoted to non-ferrous metals. The report of Committee B-1 on "Copper Wire" was read by J. A. CAPP, chairman, and of Committee B-2 on "Non-Ferrous Metals and Alloys" was read by WILLIAM CAMPBELL, chairman. A paper on "Aluminum Bronze" was presented by W. M. CORSE and G. F. COMSTOCK. A paper on "Specifications for Brass Condenser Tubes" was presented by A. E. WHITE.

The Friday afternoon session was devoted to miscellaneous materials. The report of Committee A-3 on "Cast Iron and Finished Castings" and Committee D-6 on "Coke" were read by RICHARD MOLDENKE, chairman; the report of Committee D-7 on "Timber" was read by HERMANN VON SCHRENK, chairman. The following papers were presented: "Apparatus for Testing the Standard Cast-Iron Arbitration Bar," by H. L. MORSE; "Quantitative Test for Resistance of Lubricating Oils to Emulsification," by W. H. HERSHEL; "Emulsification of Mineral Lubricating Oils," by P. H. CONRADSON.

The total registration was between 500 and 600, exclusive of about 150 ladies, for whom special features of entertainment were provided.

The Iron and Steel Market

The extreme dullness in the steel market has served to emphasize its underlying strength, for absolutely no selling pressure has been developed by the dullness, the mills all holding strictly to their former prices, while they do not offer materially earlier deliveries than they did a month ago. Instead of the market becoming dull at the beginning of July, as it usually does, it turned dull about the beginning of June, and thus a fair test has been afforded.

The mill position as to actual orders in hand makes a very strong showing. The United States Steel Corporation is stated to have 6,000,000 tons of actual shipping orders in hand, in a total of about 10,000,000 tons of unfilled obligations, showing not only a very large tonnage but a very high proportion of obligations in the form of specifications. The other large interests are assumed to be in substantially the same position.

The disclosure of such a strong mill position has caused sentiment to become much more hopeful as to the more distant future of the steel market. Hitherto the general opinion has been that the course of the market would be simply one of the orders in hand being filled, together with such orders as drift in from time to time when there is no general buying movement, and that thereafter there would be a general readjustment, with a period of lessened mill activity and a reduction in prices. Now, however, the expectation is entertained in some quarters that next fall another buying movement will be inaugurated, without any readjustment in prices, whereby the period of full activity would be prolonged well into 1917 at least. This would be an unprecedented course, for hitherto no general buying movement in steel has started at the price level at which the preceding movement left off, it being conventional for prices to decline between buying movements, but, of course, all conditions are abnormal at this time.

Export Demand

The demand for shells and shell steel, instead of being satisfied by the recent heavy buying, has continued to date, France and Italy being now in the market in a large way, and for deliveries through the first quarter of the new year. Various reports have been given circulation, chiefly in stock market circles, that munition business is declining, but these reports are not confirmed in steel circles and appear to have been promulgated for an ulterior purpose. Indications are that the production of shell steel will be greater in the second half of the year than in the first half.

The demand from the allied belligerents for classes of steel incident to the prosecution of war, other than shell steel, is very insistent, covering railroad material of all descriptions as well as ship steel. Many weeks ago Russia inquired for 350,000 tons of rails, and shortly placed somewhat more than half the tonnage with the Steel Corporation, but great difficulty has been experienced in arranging deliveries with the independents for the remainder. Bessemer steel rails have been offered, but apparently have not been accepted as yet. Russia is also inquiring in a large way for cars and locomotives.

The demand from neutral countries for steel products has continued heavy since the increase two or three months ago, and it seems probable that in the event of a decrease in domestic consumption the export business would readily take up the slack.

Finished steel prices are unchanged for forward delivery and no material change is expected for months in the important products. There has been a further diminution in the premiums asked for early deliveries of certain classes of material, and it is probable that

before long all premiums will have disappeared except on plates. The position in plates is a remarkable one, seeing that the regular mill price of 2.90c. is \$8 a ton above the regular price on shapes and bars, yet for early deliveries of plates a premium above 2.90c. regularly obtains.

Pig Iron

The condition noted in last report as to southern warrants has been largely relieved, the warrants that speculators were offering on the market at large cuts from the furnace price having been absorbed in major part. The furnace price has declined 50 cents to \$14, Birmingham, for early deliveries and the warrant market is on approximately the same basis. The northern markets have been decidedly quiet and some have shown a slight tendency toward weakness. The statistical position of pig iron is better than ever. There was a slight decrease in production in June, doubtless due to higher humidity, and the production in June, July and August promises to average less than in the preceding months, whereas the requirements of steel works promise to average more, as new steel making units are being completed from time to time and there is ample business to keep all capacity engaged. The scrap market, which had declined for three months and was exercising an unfavorable sentimental effect upon pig iron, suddenly turned strong the closing days of June and has since been advancing. Heavy melting steel has brought as high as \$17.25, delivered Pittsburgh, when a fortnight earlier it was difficult to sell at \$15.50. We quote: No. 2 foundry iron, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnace, Buffalo, \$18.50 to \$19; f.o.b. furnace, Chicago, \$19; f.o.b. Birmingham, \$14 to \$14.50; f.o.b. Valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21 to \$21.50; basic, \$18 to \$18.25; foundry and malleable, \$18.25 to \$18.50; forge, \$18 to \$18.25. Ferromanganese is much easier, prompt being frequently offered at as low as \$200, while there are reports of occasional concessions, for late 1917 delivery, from the regular contract price of \$175.

Steel

The billet market reflects great strength in the mill position. There is a heavy demand for export steel, as export demand goes, but a very light demand for domestic consumption, and that only for the earliest delivery, and the total demand is thus far from large, yet mills are very stiff in their views, frequently refusing to quote at all. Soft open-hearth steel is usually quoted at \$45, slight concessions from this price being made occasionally. Bessemer is nominally about \$43, but as a matter of fact demand for Bessemer is so light that no definite market is developed and any considerable demand might find the mills unable to quote. Discard and rejected steel, arising in the manufacture of shell steel, is less of a factor in the market, not because there is less of it but because the mills have found the market can absorb only so much of such special steel, and what they can sell they are selling in more orderly fashion, no matter how much may be left to be disposed of later, by sale as merchantable steel or by consumption as scrap.

The Non-Ferrous Metal Market

Monday, July 10.—The non-ferrous metals have continued generally dull during the last two weeks. The trust price of lead was reduced \$10 per ton, which was rather unexpected. Spelter continues its weakness.

Copper.—Copper has held fairly steady for a long time in spite of continued dullness. This has been due to the sold up condition of the market. Last week

some recessions were made, although declines were very slight. Producers ask 26c. to 27c. for fourth quarter electrolytic. Second hands offer prices slightly lower. For earlier deliveries prices ranging from 26c to 28c. are asked. The production in June is estimated at 200,000,000 lb., the exports amounting to 40,000 tons. According to estimates, the exports in the first half of the year were 145,000 tons, which is 7000 tons greater than the same period in 1915.

Tin.—Spot tin has been easy on heavy offerings, and is now quoted at about 39 $\frac{1}{8}$ c. The deliveries to consumers in June were 6398 tons, which is a record-breaking amount. Futures remain very firm, and there is only a difference of $\frac{3}{4}$ c. between spot and December deliveries. Straits tin for July delivery is quoted at 39c. with August at 38 $\frac{3}{4}$ c., September at 38 $\frac{5}{8}$ c., October at 38 $\frac{1}{2}$ c., and November at 38 $\frac{3}{8}$ c.

Lead.—The American Smelting & Refining Company reduced its price of lead to 6.50c., New York, on July 5. It was not expected, as business in lead was improving. This reduction has unsettled the market, and consumers are not buying to any extent. Independents also reduced their price to 6.45c., New York, following the trust reduction. Foreign and domestic buying was good up to July 5, considerable lead going to Russia and England.

Spelter.—Spelter continues to decline on further weakness and dropped below 10c. last week, for the first time since April of last year. Futures are stronger, and third quarter is quoted at 9c. and fourth quarter at 8c. The London spot market has also declined, and this has further depressed our market.

Other Metals.—Antimony has not touched bottom yet, and is offered at from 16c. to 17c. The market is weak and dull. Aluminum has declined slightly, and is now quoted at 60c. to 62c. Quicksilver is offered at \$80 per flask, with platinum at \$80 per oz. Silver is quoted at 62c.

Presentation of the Franklin Medal to Theodore W. Richards

At a meeting of the Franklin Institute of Philadelphia, held on May 17, 1916, the Franklin Medal was presented to Dr. THEODORE W. RICHARDS, professor of chemistry at Harvard University, and to Dr. JOHN J. CARTY, chief engineer of the American Telephone and Telegraph Company, while the Elliott Cresson Medal was presented to the American Telephone and Telegraph Company, THEODORE N. VAIL, president.

Dr. HARRY F. KELLER, for the Committee on Science and Arts of the Franklin Institute, made the presentation speeches. He pointed out that accordance to the wishes of the founder, Samuel Insull, the Franklin Medal is "awarded from time to time to those workers in physical science and technology, without regard of country, whose efforts, in the opinion of the Institute, have done most to advance our knowledge of physical science and its applications."

In reviewing Dr. Theodore W. Richards' work, Dr. Keller spoke in part* as follows:

In spite of the vast expenditures for their armies and navies in times of peace, the governments of European countries have long realized that liberal appropriations to their institutions of learning and for the promotion of scientific research is money well invested; in our country, on the other hand, the endowment of universities and research laboratories is largely dependent upon the munificence of private individuals. Nevertheless, the advancement of science in American laboratories, and by American workers, especially in recent years, has been quite abreast of that

*The complete report of all speeches may be found in the July issue of the Journal of the Franklin Institute, page 69 to 101, from which this account is taken.

in European countries; and in not a few branches of science we are proud to point to our compatriots as the peers of those abroad.

The eminent chemist who is to receive the Franklin Medal is a striking case in point. Though still in the prime of life, and looking forward, perhaps, to even greater achievements, his contributions to chemical science are universally recognized as second to none, either in number or importance, made by any contemporary investigator. Only recently the Nobel Prize of 1914 in chemistry was awarded to him, and the oldest and most famous institutions of learning in every part of the world have fairly showered upon him their highest honors and distinctions. More than a dozen universities have conferred upon him their honorary degrees; learned societies, both here and abroad, have vied with one another in electing him a member or officer; and the most highly prized trophies of chemistry, such as the Davy, the Faraday, and the Willard Gibbs Medals, have been bestowed upon him. With the award of the Franklin Medal the last great link in this great chain of honors would seem to be added.

And it seems peculiarly appropriate that this should be done in his native city. He was born in Germantown, in



THEO. W. RICHARDS

1868, the son of a well-known painter of landscapes and marines. It was there, also, that he spent most of his childhood, and where his gifted mother conducted his early education. His curiosity and interest in experimentation and science were early awakened by friends of the family, among them Dr. John Marshall of the University of Pennsylvania. At the age of fifteen he entered the Sophomore class at Haverford College, where he first seriously studied chemistry under Dr. Lyman B. Hall. After graduation in 1885, he studied Greek and entered the Senior class in Harvard, as its youngest member, in the autumn of the same year.

Since then his career, with the exception of a few and comparatively short interruptions, has had its scene in Harvard University. Graduating as A. B. in 1886, *summa cum laude*, with highest honors in chemistry, he received a fellowship in the graduate department and conducted research work under Josiah Parsons Cooke, taking the degrees of A.M. and Ph.D. in 1888. The following year he spent in Europe, visiting eminent chemists and important laboratories in various countries, and familiarizing himself with special methods of analysis and research. Returning to Harvard in 1889, he was appointed assistant, and from this position he gradually rose to that of Professor of Chemistry and Director of the recently founded Wolcott Gibbs Memorial Laboratory.

The only prolonged absences from Harvard were for the purpose of studying with some of the German masters, and, in 1907, when he was selected as Visiting Professor to the University of Berlin. Teaching a group of advanced students his methods of experimentation and research, he made a profound impression on both the students and professors. It was little short of a revelation to the German chemists that the time had arrived for reciprocity between the American and German universities in the teaching of the most advanced thought and practice in chemical research.

To sketch and characterize the work of our medallist in a few sentences—and that is all I can here attempt to do—is a difficult, an almost hopeless, task. If you consider

that ever since he graduated from Harvard in 1886 he has continuously and indefatigably been active as a teacher and investigator; that his fertile brain has planned and directed the work of great numbers of assistants and students; that his contributions to science extend over vast domains of inorganic, physical, analytical, and theoretical chemistry, and in many cases far beyond the border-line of physics; if you consider how numerous, divergent, and extended are the paths he has traveled, you will understand that only a very few of the high lights can here be pointed out.

Best known and, in certain respects, most important, are the researches on the atomic weights of more than twenty of the chemical elements. These elements were not chosen at random, but very carefully selected with a view to solve chemical problems of fundamental importance. The papers published on this work extended over many years, and must be counted among the classics of chemical literature. They reveal the masterly reasoning of the author, his fertile scientific imagination, his resourcefulness and skill as an experimenter. They abound in the description of new observations, new methods, and new forms of apparatus. The atomic weights themselves are determined with the utmost precision that the resources of modern science permit.

It was from the investigation of the fundamental properties of the elements that most of his other researches took their starting-points. Among them are the studies of the compressibility of elements and compounds; of the changes in atomic volume; of the birth of crystals as revealed by micro-photography and the kinoscope; of thermochemical, electrochemical, and, lately, also of radiochemical problems. His hypotheses concerning the sour taste of acids and the compressibility of atoms are noteworthy contributions to theoretical chemistry, and he has also devised one of the best methods of teaching elementary chemistry.

As, due to illness, Dr. Richards was unable to be present, the president announced that the medal and accompanying certificate would be forwarded to him. Dr. George A. Hoadley then read the following address for Professor Richards:

The Essential Attributes of the Elements

BY THEODORE W. RICHARDS

We come together to-day, in this world-renowned Institute, founded in honor of one of the greatest of our countrymen, to participate in an annual celebration of progress in pure and applied science. Franklin himself would have heartily approved of such an annual celebration; he was deeply interested in the study of Nature, and profoundly convinced of the importance to humanity of exact knowledge and its practical application. Inspired by his conviction of the usefulness of science, he founded here in Philadelphia the oldest American scientific society, and here he performed the first significant experiments in physics of the New World. He would have eagerly supported the Institute in its aims and activities, and he is fittingly commemorated in its name.

To be included in this celebration of scientific advance in the home of Franklin, my own native city, is a privilege; and I beg to express my hearty appreciation of the very great honor which the Institute has conferred upon me.

As the title on the program indicates, my pleasant duty now is to speak to you on the fundamental properties of the elements, which have formed the chief subject of my chemical and physical studies. At the outset one may well ask: What are the elements, and what shall we designate as their fundamental properties? In these iconoclastic days several of our old scientific idols seem to have been shattered. If uranium and radium are only transitory, may not the other so-called "elements" also be slowly decomposing? In this case, ought we to count them as elements at all? Moreover, if, as some suppose, the atom is made up of nothing but electrons (positive and negative), what has become of the old atomic theory?

These questions, disturbing although they may seem

to be, are easily answered. Perhaps, from a philosophical and etymological point of view, the chemical atom no longer deserves its name; but the fact remains that in all the ordinary affairs of life our relations with the chemical elements primarily concerning us are unchanged by all the fascinating new knowledge. These same old elements remain as permanent as they ever were; and the only satisfactory explanation of the definite proportions by weight in which they combine is now, as of yore, the assumption of ultimate, undestroyed (if not indestructible) particles or chemical "atoms." The atomic theory is indeed even more convincing today with regard to mundane chemical affairs than it was before the dawn of radio-activity.

Of course, no one pretends nowadays that the chemical elements are to be considered as absolutely incapable of decomposition. Even supposing, however, that in the hottest stars some of them disintegrate, on earth, at least, they are amazingly permanent. It is concerning the earthly chemical elements, therefore—the old-fashioned kind of half a century ago—that I have to speak.

These elementary chemical substances build up everything about us, as well as our own bodies. It has always seemed to me, therefore, that the fundamental attributes which determine their behavior are worthy of very careful scrutiny.

Among the most fundamental of attributes, if not the most significant of all, is the tendency possessed by the elements to combine in definite proportions by weight. This we explain, as already stated, by the assumption that all matter is made up of atoms. One cannot believe that these atoms should have anything so important as their weight decided by mere chance or accident. Therefore, I chose the study of the atomic weights as the first of the fundamental properties to be investigated, and perhaps half of my time during the last thirty years has been devoted to this subject.

Great accuracy in the work was sought for several reasons, the most important of which was an earnest desire to find if possible the suspected mathematical relationship between these fundamental quantities. Such a relationship, if discovered, would greatly deepen our insight; and if it is to be found the data to be compared must be determined as accurately as possible.

Another reason for taking great pains in determining atomic weights is the fact that these figures are used by chemists throughout the world in their daily work oftener than any other series of data. All the manifold happenings of Nature occur in material built up of these same atoms. If we are to analyze or synthesize, or in any way have to do with the quantitative relations of reacting chemical substances under any circumstances, we must ultimately turn to the atomic weights for help. It is not too much to say that the atomic weights are the basis of quantitative chemistry.

More than two thousand years ago Plato said: "If from any art that which concerns weighing, measuring and arithmetic is taken away, little remains of that art." To-day we may paraphrase this saying as follows: "If from chemistry are taken away the atomic weights (or other numerical data representing the same definite proportions), little will remain of that science." As a science becomes more scientific it becomes more quantitative, and greater accuracy in the determination of its fundamental mathematical basis is required.

There is not time this afternoon to go into the details of many determinations of nearly thirty atomic weights carried out during as many years at Harvard. The effort was made to build upon the basis provided by the careful work of Berzelius, Marignac and Stas, with the help of the new discoveries in physical chemistry concerning solubility, hydrolysis, adsorption, and solid solu-

tion. Metals were compared, as to their combining proportions, especially with chlorine, bromine and iodine; moreover, many other careful comparisons likewise were made, as, for example: oxygen with silver through lithium chloride and lithium perchlorate; silver into nitrogen and sulphur through silver nitrate and sulphate; oxygen with carbon and sulphur sodium carbonate and sulphate, and many others. These, taken together, tend to put our whole table of atomic weights upon a stabler basis. The elements of which the atomic weights have been determined under my own immediate supervision are the following: copper, barium, strontium, calcium, magnesium, zinc, nickel, cobalt, iron, uranium, caesium, sodium, potassium, chlorine, nitrogen, silver, sulphur, carbon, lithium and radio-lead. To these should be added, as part of the Harvard contribution, those studied by my most energetic pupil in this line of work, Prof. G. P. Baxter, long since an independent investigator on his own account: arsenic, bromine, cadmium, chromium, iodine, lead meteoric iron and nickel, manganese, neodymium, praseodymium, and phosphorus. The most interesting outcome of my work is perhaps the discovery that lead from radio-active minerals possesses an atomic weight distinctly less than that of ordinary lead—206.1 instead of 207.2—although it gives the same spectrum.

If I were to sum up in a few words the lessons of these protracted investigations, I should be inclined to say that the secret of success in the study of atomic weights lies in carefully choosing the particular substances and processes employed, and in checking every operation by parallel experiments so that every unknown chemical and physical error will gradually be ferreted out of its hiding-place. The most important causes of inaccuracy are: the solubility of precipitates and of the material of containing vessels; the occlusion of foreign substance by solids, and especially the presence of retained moisture in almost everything. Each of these disturbing circumstances varies with each individual case. Far more depends upon the intelligent choice of the conditions of experiment than upon the mechanical execution of the operations, although that, too, is important. I have often quoted the innocent remark which has occasionally been made to me: "What wonderfully fine scales you must have to weigh atoms!" and have endeavored to point out that the purely chemical work, which precedes the introduction of the substance into the balance-case, is much more important than the mere operation of weighing.

Laboratory work alone can furnish us with accurate values of the atomic weights. No speculative method involving higher mathematics has as yet been able to solve definitively the cosmic puzzle of their relative magnitudes. In this direction, as in many others, chemistry is still largely an inductive science. When we have discovered the realities, we shall be in a position to attempt to explain them. In the meantime more accurate views, discovered little by little through patient investigation will be of use to the thousands of men throughout the world who daily employ these fundamental data of chemistry.

Matter possesses not only the fundamental properties of weight and mass, measured (from the chemical point of view) by the combining proportions of the elements, but also an equally fundamental attribute which causes it to occupy space. Thus, side by side with the study of weight and mass, the study of volume deserves close attention. This latter property is more changeable and more puzzling in its varied manifestations than the constant attributes of weight and mass. Almost every solid expands, occupying more space as it is heated, expands yet more in the act of melting, and finally

swells up into an altogether disproportionate volume when it is converted into vapor. In each of these states of matter the application of pressure produces a lessening of the volume—very small, but still perceptible in the case of solids, usually greater in the case of liquids, and still very much greater in the case of gases. The behavior of gases is very similar in each case: here the molecules must be far apart. On the other hand, solids and liquids behave in a manner entirely different from gases and entirely different from one another. The molecules must be very near one another, and the specific nature of each must come greatly into play. Even for any single substance the space-filling relations of the solid and liquid form are highly complex, and when comparison is made between different substances the complexity is vastly increased; yet none of these varying manifestations of the property of occupying space can be accidental. Each must have its inner significance, and the relation of each to the other cannot but be fundamentally connected with the ultimate nature of the substance concerned. Some of the relations are opened to us by the science of thermodynamics; but many of the data must be found, like the atomic weights, by experiment alone.

These considerations led me, nearly twenty years ago, to begin the study not only of the space occupied by the elements, especially in their liquid and solid states of aggregation, but also of many other related fundamental properties of the elements and their compounds, including the effect of increasing temperature and increasing pressure. Some of the data needed in this study had already been provided by the preceding work of others, but particularly in the case of compressibility, of which I wish especially to speak, very few data had been gathered even as recently as fifteen years ago. Only three or four elements had been carefully studied, and these by methods of doubtful efficacy. Hence the first step was to devise a simple and accurate method capable of determining the exceedingly small compressibilities of the solid elements. This method was devised in 1903, and with its help the compressibilities of nearly forty elements have been determined with sufficient accuracy to trace with some precision their relations to one another and to the bulk occupied by these same elements. Bridgman has since carried the determination of a few of these to much higher pressures.

The outcome is highly interesting. If the elements are arranged in the order of their atomic weight, we find that the compressibilities show a very well-marked alternating periodic increase and decrease as the atomic weight progresses. This fluctuation parallels in remarkable fashion the periodicity of the atomic volumes noticed long ago by Lothar Meyer. It appears that when an element has a large atomic volume (that is to say, when the bulk occupied by its atomic weight in grammes is large) the compressibility also is large, and *vice versa*; and the changes are of the same order in the two cases. That these two properties are fundamentally connected no one can doubt after studying the parallel curves showing their similar progression with increasing atomic weight. Neither can one doubt that in the tracing of this parallelism a real step has been made in the study of the nature of the element.

Other properties, more or less related, also have been shown to have analogous rhythms.

One may well ask: Can any conceivable interpretation be found for such parallel rhythms, analogous to Dalton's interpretation of the combining weights of the elements? In other words, can we refer effects concerned with the space occupied by gross matter to the atoms themselves, somewhat as the combining proportions of the elements are referred to the weights of the atoms? It seems to me that this can be done.

If one assumes that the practical bulk of the atoms in solids and liquids is compressible, most of these results fit naturally into their expected places. Those atoms which are much distended (that is to say, have large atomic volume) would be expected to be the most compressible. We should expect also to find that increasing chemical affinity, by pulling the atoms more and more together, would likewise cause compression and, therefore, diminish volume; and cohesive affinity would have the same effect. There is much evidence to show that this interpretation is a reasonable one, but time forbids again that the details should be entered into here. The hypothesis is pragmatic; it considers, not the hypothetical space which may or may not be occupied by an imaginary center or core in the atom, but rather the space which the atom actually requires in solids and liquids. That this space is definite and significant is proved beyond cavil by such curves as those to which I have referred, as well as many other facts concerning solids and liquids. One may well hope that the combined following of this trail may lead one to heights from which a broader view of the materials constructing the universe may be obtained. But even if the hypothesis should some time be found wanting, it has served already a purpose helpful to progress, for it has stimulated many researches leading to the acquisition of new facts. These will stand in the future, whatever may be the fate of the theory.

Do these investigations concerning ultimate properties of things and these hypotheses concerning the correlation of the properties seem to be remote from the pressing problems of humanity? Not so. We must remember that applied science follows in the footsteps of theoretical science. The laws of chemistry cannot be adequately applied until they have been discovered. Only by researches delving into the hidden secrets of Nature by some such processes as these can new discoveries in the realm of pure science be made; and no one can tell how great may be the gain to the philosophy of Nature, as well as to the daily lives of men.

The vital importance of chemistry to modern civilization is well known to this distinguished audience. Someone has wisely remarked that, whereas the nineteenth century was primarily devoted to advance in mechanical and electrical directions, the twentieth century bids fair to be an essentially chemical century. In war—now, alas! devastating the earth—as well as in the lasting peace for which we hope, chemistry is bound to play an all-important part. We perceive that every manufacture is concerned with chemical substances; we realize that recent chemical discoveries have revolutionized the preparation of many things essential to our life and have initiated entirely new industries of great importance and benefit to mankind. The great war has only intensified our appreciation of these facts. We recognize also that even we ourselves, so far as our material existence is concerned, are chemical machines, and that our every thought and act is intimately bound up with chemical reactions, without which neither thought nor act could come into being. Let us hope that the triumphs of chemistry in the future will be used not only for furthering manufacture and agriculture, thereby rendering life more comfortable and prosperous; but, also, above all, for advancing hygiene and medicine to a point where the physician will be able really to understand the complex anomalies which confront him every day. Let us hope, too, that with this practical progress may be united the growth of a broader and saner philosophy of Nature, founded upon a truer knowledge of the materials composing the universe and of the energy which animates it. To such ends, full of blessing to humanity, let us dedicate the science in the future.

The Dyestuff Tariff Before Congress

When in our issue of April 15, 1916 (page 407), we commented on the defeat in the Senate of the Lodge dyestuff tariff amendment to the sugar bill, we remarked that it seemed unbelievable that this should be the end of the dyestuff tariff fight in the present Congress, and that we preferred to take it as part of the political game. This view has proven true. The dyestuff tariff fight has been renewed, and the game is on again, through the action of the Ways and Means Committee.

The new general revenue bill of the Administration, now before Congress, contains besides provisions for an increased income tax and for a tax on gross receipts from the sale of munitions of war, also a provision for the creation of a tariff commission, as proposed in the recent bill offered by Mr. Rainey of Illinois, further an anti-dumping clause, and a new dyestuff tariff.

The anti-dumping clause reads as follows:

"That it shall be unlawful for any person importing or assisting in importing any article from any foreign country into the United States to commonly and systematically sell or cause to be sold such articles within the United States at a price substantially less than the actual market value or wholesale price of such articles, at the time of exportation to the United States, in the principal markets of the country of their production, or of other foreign countries to which they are commonly exported, after adding to such market value or wholesale price freight, duty and other charges and expenses necessarily incident to the importation and sale thereof in the United States.

"Provided, that such act or acts be done with the intent of destroying or injuring an industry in the United States or preventing the establishment of an industry in the United States, or of restraining or monopolizing any part of the trade or commerce in such articles in the United States.

"Persons convicted of violating this provision are punishable by a \$5,000 fine or one year's imprisonment or both. Any person injured by violations may sue the defendant and recover threefold damages sustained and costs."

The proposed new dyestuff tariff is as follows:

"Sec. 400. That on and after the day following the passage of this act, except as otherwise specially provided for in this title, there shall be levied, collected and paid upon the articles named in this section when imported from foreign countries into the United States, or into any of its possessions, except the Philippine Islands and the islands of Guam and Tutuila, the rates of duties which are prescribed in this title, namely:

"Free List—Group I. Acenaphthene, anthracene, benzol, carbazol, cresol, cumol, fluorene, methylantracene, methylnaphthalene, naphthalene, pyridin, quinolin, toluol, xylol, crude coal tar, pitch of coal tar, dead or creosote oil, anthracene oil, all other distillates which on being subject to distillation yield less than 5 per centum of tar acids in the portion of distilling below 200 deg. C., and all other products that are found naturally in coal tar, whether produced or obtained from coal tar or other source, and not otherwise specially provided for in this title, shall be exempt from duty.

"Dutiable List—Group II. Amidonaphthol, amidophenol, amidosalicylic acid, aniline oil, aniline salt, anthraquinone, binitrobenzol, binitrotoluol, binitronaphthalene, binitrochlorobenzol, benzaldehyde, benzylchloride, benzinidin, chlorphthalic acid, cumidin, dianisidin, dimethylanilin, dioxynaphthalene, diphenylamin, methylanthraquinone, metanilic acid, nitrobenzol, nitrotoluol, nitronaphthalene, nitraniline, nitrophenylenediamine, nitrotoluenediamine, naphthylamine, naphthol, naphthylenediamine, phenol, phthalic acid, phthalic anhydride,

phenylenediamine, phenylnaphthylamine, resorcin, salicylic acid, sulfanilic acid, toluidin, tolidin, tolylenediamine, xylidin, or any sulfoacid or sulfoacid salt of any of the foregoing, all other distillates which on being subjected to distillation yield 5 per centum or more of k.r. acids in the portion distilling below 200 deg. C., and all other products obtained, derived or manufactured in whole or in part from the products provided for in Group I, all the foregoing not colors, dyes or stains, photographic chemicals or explosives, and not otherwise provided for in this title, 15 per centum ad valorem.

Group III. All colors, dyes or stains, whether soluble or not in water, color acids, color bases, color lakes, photographic chemicals or explosives, not otherwise specifically provided for in this title, when obtained, derived or manufactured in whole or in part from any of the products provided for in Groups I and II, including natural alizarin and indigo, 30 per centum ad valorem.

"Sec. 401. That on and after the day following the passage of this act, in addition to the duties provided in Sec. 400, there shall be levied, collected and paid upon all articles contained in Group II a special duty of 2½ cents per pound, and upon all articles contained in Group III (except natural and synthetic alizarin and dyes obtained from alizarin, anthracene and carbazol; and natural and synthetic indigo and all indigoids, whether or not obtained from indigo), a special duty of 5 cents per pound.

"During the period of five years, beginning five years after the passage of this act, such special duties shall be annually reduced by 20 per centum of the rate imposed by this section, so that at the end of such period such special duties shall no longer be assessed, levied or collected; but if at the expiration of five years from the date of the passage of this act the President finds that there is not being manufactured or produced within the United States as much as 60 per centum in value of the domestic consumption of the articles mentioned in Groups II and III of Sec. 400, he shall by proclamation so declare, whereupon the special duties imposed by this section on such articles shall no longer be assessed, levied or collected.

"Sec. 402. That paragraphs 20, 21, 22 and 23 of Schedule A of Sec. 1 of an act entitled 'An act to reduce tariff duties and to provide revenue for the government, and for other purposes,' approved Oct. 3, 1913, and paragraphs 394, 452 and 514, and the words 'carbolic' and 'phthalic' in paragraph 387 of the 'free list' of Sec. 1 of said act, and so much of said act or any existing law or parts of the law as may be consistent with this title are hereby repealed."

To understand clearly the scope of the proposed new dyestuff tariff of the *Kitchin bill* just quoted, it must be compared with the *Underwood tariff*, now in force since 1913, and with the proposed *Hill bill*, based on the recommendations of the chemical and dyestuff committee of the New York Section of the American Chemical Society, of which full details were given in our issues of December, 1914, Vol. XII, page 753, and Feb. 1, 1916, Vol. XIV, page 125.

From present developments it is evident that without exception everybody agrees that the rates of the *Underwood tariff* are absolutely insufficient. It provides a duty of 30 per cent ad valorem on aniline dyes and 10 per cent on intermediates, alizarin and anthracene dyes and indigo are free. There is no surtax per pound on anything.

The *Hill bill* represents what would be needed for such purpose according to the unanimous convictions not only of the present American dye makers, but of the American chemical industry in general.

The Kitchen bill introduces a new and very interesting feature into tariff matters by proposing a time limit (second paragraph of Sec. 401 quoted above). But it differs from the Hill bill also in two other points.

Firstly, with respect to the intensity of protection (value of duty), the Hill bill places a duty of 15 per cent ad valorem on intermediates and 30 per cent on finished dyes; the Kitchen bill does the same. But in addition to this, the Kitchen bill adds a "special duty" of 2½ cents per pound on the intermediate and 5 cents per pound on finished dyes, while the Hill bill provides for 3¾ cents per pound on the intermediates and 7½ cents per pound on finished dyes. Thus the amount of the special duty considered necessary by the chemical industry according to the Hill bill is reduced in the Kitchen bill by 33 1/3 per cent.

Secondly, with respect to the width or extension of the protection, the Hill bill tries to protect the new dyestuff industry all around. The Kitchen bill does not, as it exempts alizarine, anthracene and indigo from the additional "special duty" (Sec. 401, first paragraph).

Other matters have naturally come up, such an appeal to place an equal duty on coal-tar medicinals as on dyestuffs. Without entering into a discussion of the fairness of such a proposal, we do not think it likely that the present Congress will do much more than decide between the Kitchen bill and the Hill as they stand. On what we believe are the principal points to be considered in reaching this decision we comment on our first editorial page.

Metallurgy in Ontario

The annual report of Arthur A. Cole, engineer for the Ontario Government Railway, on the mining industry in northern Ontario during 1915, has just been issued. As usual, it contains an unusual amount of interesting information and data on mining and metallurgy in the remarkable Cobalt and Porcupine districts. Ontario is now the largest gold and silver-producing Province in Canada, yielding 44 per cent of the gold and 87 per cent of the silver. The increased cost of supplies during 1915 was partly compensated by the increased price of metals, but the greatest compensation came in the way of improvement in the work whereby costs per ton were materially reduced. The following comparative statement of the cost of milling supplies used at Cobalt will give an idea of the increase that has taken place:

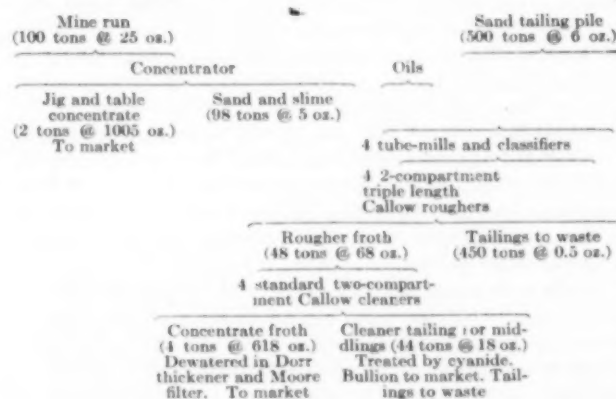
Material	Ante-Bellum	March, 1916
Aluminium dust, lb.	\$0.34-\$0.38	\$0.75-\$0.90
Caustic soda, 100 lb.	1.30	7.50
Chrome-steel balls, 100 lb.	4.16	7.58
Cyanide—contract, lb.	0.15	0.16
Cyanide—no contract, lb.	0.15	0.20
Mercury, flask, 75 lb.	37.00	200.00-300.00
Pebbles, French, ton f.o.b. New York	9.75	13.25
Pebbles, Danish, ton f.o.b. New York	13.00	15.00-16.00
Soda ash, 100 lb.	1.27	3.91
Sulphuric acid, 100 lb.	1.30	1.95
Zinc dust, lb.	0.065	0.33-0.35

At Porcupine, which is about 100 miles northwest of Cobalt, still higher prices have prevailed and advances of from 8 per cent to 427 per cent in the cost of mill supplies is recorded.

Porcupine continues to be the principal gold-producing camp, and the output for 1915 was valued at \$7,580,766, as against \$5,203,229 for 1914. Cobalt is the main source of silver, having produced 234,000,000 ounces since its discovery in 1904. The output for 1915 was 23,653,713 ounces, a decrease from the previous year when the output was 25,162,841 ounces. The production of silver from Cobalt has constantly decreased since

1911, when the high point of 31,507,791 ounces was reached. There were nine companies at Cobalt, each of which produced more than one million ounces of silver during 1915. Dividends and bonuses paid by Cobalt companies in 1915 amounted to \$4,523,415; the grand total since the discovery of the camp is \$57,614,202.

A number of Cobalt companies are now employing the flotation process. The largest plant is that of the Buffalo company, which experimented first with a 50-ton plant of the Callow pneumatic type. A permanent plant of 600 tons capacity is now being erected for the treatment of 500 tons per day of accumulated tailings from water concentration and of 100 tons of mine rock. The fine-grinding equipment will consist of four 5 ft. 6 in. by 20 ft. tube-mills, and the flotation plant of four two-compartment, triple-length Callow cells to be used as roughers and four standard two-compartment cells as cleaners. The old cyanide plant will be used for de-watering flotation concentrate and for the cyanidation of flotation middling. A flow-sheet of the flotation plant is herewith given.



The Vulcan Soot Cleaner Company has recently issued a catalog describing its product, the Vulcan soot cleaner. The catalog is nicely illustrated and the frontispiece is a four-color reproduction of actual specimens of soot from different boilers and with different fuels. The different sections of the catalog contain complete information as to what soot really is, and how it can be economically removed.

Potash in British Columbia.—The Canadian Potash and Algin Co. (Ltd.) was organized in 1915 and a plant established at Sydney, British Columbia. It is now utilizing from 30 to 40 tons of raw kelp daily in the manufacture of fertilizer, according to Commerce Reports. The product is a fine, dry, but heavy powder. Plans are being made to enlarge the plant and install special machinery for the extraction of other materials from kelp.

It is believed by the promoters of the industry in this Province that the manufacture of iodine and potash, without the production of by-products, would not prove very profitable in normal times, but the increase in the price, especially of potash, on account of the war, will enable the British Columbia company to include these and other by-products in the output of the factory at Sydney.

Algin, which will be made one of the specialties of the local plant, is said to possess a viscosity many times greater than that of starch or gum arabic. The chief use of algin is for the sizing of fabrics, the effect being to give the material treated the appearance of waterproof sheeting, but leaving it more elastic than when treated by other customary waterproofing materials.

Catalysis in the Formation of Gasoline from Kerosene

BY GUSTAV EGLOFF AND ROBERT J. MOORE

In the formation of gasoline from heavier petroleum oils three distinct methods may be recognized:

1. THE TWO-PHASE SYSTEM, GAS AND LIQUID.
 - a. Distillation in an ordinary still at atmospheric pressure.
 - b. Distillation under greater than atmospheric pressure.
2. THE ONE-PHASE SYSTEM, GAS.
 - a. The cracking takes place at atmospheric pressure.
 - b. The cracking takes place at greater than atmospheric pressure.
3. THE THREE-PHASE SYSTEM, GAS, LIQUID AND SOLID.

The dissociation of the heavier hydrocarbons into lighter hydrocarbons takes place by the use of catalytic and chemical agents.

Of the three methods the two-phase system is the oldest. In this system there is always present liquid oil in the still in equilibrium with the oil gas above the liquid layer. Silliman¹ in 1855 predicted that in ordinary distillation of heavy oils decomposition takes place, giving lighter oils. Since that time various processes have been devised for the production of the more valuable oils as the particular uses of the times called for. Before the advent of motor cars the production of kerosene was important, at present gasoline has become the primary product. The most important process now for the increased production of gasoline is the Burton.² This is a gas-liquid system under a pressure of approximately seventy pounds. Other important processes of the first mentioned type are those of Brooks, Bacon & Clark,³ and Snelling.⁴

THE GAS-PHASE METHOD

The gas-phase method has come rapidly to the fore in the past few years. This system is fundamentally different from the foregoing one in that no liquid is present and only the vaporized oil is cracked. Not much has been done with this system, however, at atmospheric pressure due to the highly unsaturated aliphatic formation and low yields of gasoline.⁵

The gas-phase method under pressures greater than atmospheric has been thoroughly worked out by Rittman.⁶ He has thermolized paraffin, paraffin-asphaltic and asphaltic base petroleum, kerosene, gas oils and fuel oils in the gaseous phase under pressure.

THE THREE-PHASE METHOD—GAS, LIQUID AND SOLID

In the use of catalysis for the conversion of heavy oils to light boiling fractions a number of metals and their chlorides have been tested. Those usually adopted for their catalytic effect have been aluminium, zinc and magnesium.

The method usually employs anhydrous aluminium chloride or passes hydrogen chloride or chlorine over metallic aluminium in a still. In this reaction the solid phase, aluminium or its chloride, is in equilibrium with the liquid oil and the gas above it. Friedel and Craft⁷ published in 1878 the findings that aluminium chloride gave in contact with heavy oils, oils of a much lower

volatility. G. W. Gray⁸ in 1913 took out two process patents upon this idea as also did McAfee⁹ in 1915. McAfee specifies the use of metals for the formation of gasoline, paraffin and lubricating oils from heavy petroleum. He describes the action of anhydrous aluminium chloride upon three type oils: paraffin, paraffin asphaltic and asphaltic base oils. By the use of anhydrous aluminium chloride the results given in Table 1 were obtained by him:

TABLE I

	Per Cent Gasoline
Paraffin base oil on the basis of crude oil used.....	21.48
Paraffin asphaltic base on the basis of crude oil used.....	14.58
Asphaltic base on the basis of crude oil used.....	17.45

OBJECT

The formation of gasoline from the thermal and pressure decomposition of heavy oils in the gas-liquid condition has been thoroughly studied. Rittman's work upon the gas phase system of thermal and pressure decomposition of various oils for the production of gasoline has been inclusive. Contrasted with the work that has been done on the gas-phase and the gas-liquid system, comparatively little material can be found on the gas-liquid-solid system. It was with the view of getting more definite information on this latter type system that the following experiments were undertaken. Thus the effect of the catalytic or chemical action of the chloride of metals and non-metals upon gasoline formation from a paraffin base kerosene has been studied.

Experimental Procedure

The experiments were carried on in an 800-c.c. Kjehldahl flask fitted with a two-holed cork stopper. Through one hole was attached a Glinzky distilling head connected to a 24-in. Liebig condenser. Through the other hole a glass tube extended to the bottom. Through this was passed the hydrogen chloride gas generated in a Freas apparatus by dropping concentrated sulphuric acid on ammonium chloride. The gas was washed and regulated by a Dreschel wash bottle containing concentrated sulphuric acid. The chlorine used was generated by dropping concentrated hydrochloric acid on potassium permanganate.

A charge of 400 or 500 c.c. kerosene and 10 per cent by weight of the catalyst was placed in the Kjehldahl flask, which was made airtight with sodium silicate and collodion, and heated in each case with a uniform size Bunsen flame. The average time of reaction was three hours.

The distillate in each case was measured and washed in a separatory funnel with sodium hydroxide solution. The oils from the phosphorus and selenium runs gave a bad odor due to the formation of phosphine and hydrogen selenide. After taking its specific gravity, 100 c.c. of oil was distilled in a standard Engler 100 c.c. flask, the cut to 150 deg. C. being taken as gasoline.

The characteristics of the reaction and the appearance of the distillates differed widely in the various runs. The color and clarity of the residue left in the Kjehldahl flask varied all the way from a slight reddish tinge and insignificant red precipitate, in the case of selenium, to a black muddy sludge, in the case of aluminium. This sludge, which appeared in several of the runs, was partly volatile and condensed in the Glinzky head and condenser, and even came over into the distillate offering a certain amount of annoyance in clogging the apparatus. In the chlorine runs on phosphorus and sulphur the combination to form chlorides was so strongly exothermic that flashes of light were con-

¹Report on rock oil or petroleum from Venango Co., Pa., New Haven, 1855.

²Burton; U. S. Patents 1,049,667; 1,105,961.

³Brooks, Bacon & Clark; U. S. Patent 1,131,309; *J. Ind. & Eng. Chem.*, Vol. 7, 1915.

⁴Snelling; *Bull. Am. Inst. Min. Eng.*, 100,695, 1915.

⁵Egloff and Twomey, *Jour. Phys. Chem.*, 20,121, 1916; *MET. AND CHEM. ENG.*, 14,247, 1916.

⁶Rittman; *J. Ind. Eng. Chem.*, 7,945, 1015; Bulletin 114, Bureau of Mines.

⁷*Chem. Ind. Jahr.*, 1411, 1878. English patent 4769, 1877.

⁸English patents 17,838 and 17,839.

⁹*Jour. Ind. Chem. Eng.*, 7,737, 1915; *MET. AND CHEM. ENG.*, 13,592, 1915; *National Petr. News*, 720, 1915; U. S. Patent 1,127,465.

tinually emitted under the oil and the system continued at boiling, even when the burner was removed.

OIL USED

The oil used in these experiments was a water white kerosene derived from a paraffin base Pennsylvania crude petroleum. The oil analyzed as stated in Table 2.

TABLE II

Specific gravity.....	0.800 at 15.5 deg. C.
Nitration test.....	0.8 per cent combined
Sulphuric acid test.....	0.2 per cent combined

DISTILLATION TEST USING STANDARD 100-C.C. ENGLER FLASK

FIRST DROP 153 DEG. C.

Temperature	Per Cent by Volume
Deg. C.	2.0
160	9.5
170	22.0
180	35.5
190	46.0
200	56.0
210	65.5
220	73.0
230	80.0
240	86.0
250	13.2
Residue	0.8
Loss	

Experiments

With hydrogen chloride five different elements were used, sodium, magnesium, aluminium, zinc and selenium. With chlorine were used sulphur, selenium, phosphorus, silicon, aluminium and magnesium. With the exception of sulphur, phosphorus and sodium, which soon melted under the heated oil, the elements were used in a finely-powdered form.

EXPERIMENTAL DATA

TABLE III—PER CENT RECOVERED, SPECIFIC GRAVITY AND DISTILLATION ANALYSIS OF THE RECOVERED OIL. FOR HYDROGEN CHLORIDE

	Sodium	Magnesium	Aluminium	Zinc	Selenium
Per cent recovered.....	70.0	75.1	71.0	70.0	45.0
Specific gravity.....	0.781	0.781	0.750	0.770	0.771
1st distil. drop.....	140 deg.	143 deg.	31 deg.	135 deg.	132 deg.
Per cent to 150 deg. C.....	7.5	1.5	52.5	7.0	4.0
Per cent to 160 deg.....	20.0	9.0	61.5	16.5	35.0
Per cent to 170 deg.....	37.5	35.5	75.0	38.0	70.0
Per cent to 180 deg.....	55.0	55.0	84.0	58.0	85.0
Per cent to 190 deg.....	71.5	70.0	88.5	73.0	92.0
Per cent to 200 deg.....	85.5	81.0	92.5	85.0	.....
Per cent to 210 deg.....	95.0	88.0	.....	92.0	.....
Per cent gasoline on basis of recov. oil.....	7.5	1.5	52.5	7.0	4.0

TABLE IV—PER CENT RECOVERED, SPECIFIC GRAVITY AND DISTILLATION ANALYSIS OF THE RECOVERED OIL. FOR CHLORINE

	Magnesium	Aluminium	Silicon	Phosphorus	Sulphur	Selenium
Per cent recovered.....	67.5	73.8	60.0	55.0	67.5	48.0
Specific gravity.....	0.795	0.778	0.796	0.789	0.788	0.780
1st distillation drop.....	148 deg. C.	62 deg. C.	146 deg. C.	134 deg. C.	140 deg. C.	135 deg. C.
Per cent to 150 deg. C.....	0.5	21.5	1.0	3.0	1.0	11.0
Per cent to 160 deg.....	8.5	31.5	12.0	18.5	9.5	33.0
Per cent to 170 deg.....	27.0	55.0	34.0	39.0	32.0	59.5
Per cent to 180 deg.....	46.5	62.0	55.5	58.0	54.0	81.5
Per cent to 190 deg.....	62.0	78.0	74.0	73.5	75.0	92.0
Per cent to 200 deg.....	76.0	88.5	84.5	85.0	87.0	.....
Per cent to 210 deg.....	84.5	94.5	92.0	91.0	95.0	.....
Per cent gasoline on basis of recovered oil.....	0.5	21.5	1.0	3.0	1.0	11.0

Discussion of the Data

Table 3 tabulates the analytical results of passing hydrogen chloride over the metals sodium, magnesium, aluminium, zinc and the non-metal selenium in the conversion of kerosene to gasoline. The per cent of oil

recovered, the specific gravity and distillation figures of the recovered oil are given. It is to be noted that aluminium chloride gives a specific gravity of 0.750 and the first drop from the end of the condenser at 31 deg. C., which gives an idea of the high volatility of the converted oil. The other metals and non-metal give gravities of the recovered oil ranging from 0.770 to 0.781 and the first drop from 132 deg. C. to 143 deg. C. The yield from aluminium and hydrogen chloride treatment of kerosene in the recovered oil is 52.5 per cent gasoline, whereas, the others range from 1.5 to 7.5 per cent. No satisfactory explanation is at hand why aluminium chloride should give such greatly increased yield of gasoline when compared to the chlorides of the other elements.

TABLE V—THE PER CENT OF GASOLINE UPON THE BASIS OF OIL USED FROM THE PASSING OF HYDROGEN CHLORIDE OVER METALS AND NON-METAL

	Magnesium	Selenium	Zinc	Sodium	Aluminium
Per cent gasoline.....	1.1	1.8	4.9	5.3	37.3

TABLE VI—THE PER CENT OF GASOLINE UPON THE BASIS OF OIL USED FROM THE PASSING OF CHLORINE OVER METALS AND NON-METALS

	Magnesium	Silicon	Sulphur	Phosphorus	Selenium	Aluminium
Per cent gasoline.....	0.3	0.6	0.7	1.7	5.3	15.9

Table 4 tabulates similarly to Table 3 the results of passing chlorine over the metals magnesium, aluminium, and the non-metals silicon, phosphorus, sulphur and selenium.

The specific gravity of the recovered oil from aluminium chloride treatment gave 0.778, with 62 deg. C. for the first drop. The chlorides of the other elements gave a specific gravity range of 0.780 to 0.796 and first drop between 134 deg. C. to 148 deg. C. The per cent of gasoline formation in the recovered oil for aluminum chloride was 21.5, and for the other chlorides between 0.5 to 11.0 per cent. Again the chloride of aluminium gave a much higher yield than the other chlorides.

A comparison of Tables 3 and 4 indicates clearly the higher yields of gasoline from the aluminium chloride formed by passing hydrogen chloride over the metal in comparison with its formation from chlorine. Excess of chlorine in the sphere of the reaction seems to inhibit somewhat the velocity of the reaction in gasoline formation from kerosene, whereas the hydrogen chloride excess increases the reaction velocity. Furthermore excess of hydrogen chloride reduces the unsaturated compound formation to a negligible amount in the gasoline fraction.

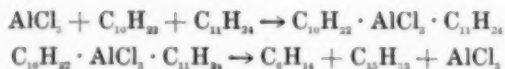
Tables 5 and 6 give the per cent of gasoline formation upon basis of the original kerosene used. Aluminium chloride formed from hydrogen chloride and aluminium gave 37.3 per cent, whereas using chlorine in its formation 15.9 per cent gasoline resulted. The per cent of gasoline from the chlorides of the other metals ranged between 0.3 to 5.3 per cent.

The Mechanism of the Reaction

As to whether the action of the chlorides of the metals or non-metals is simply that of an activator in the formation of low-boiling from high-boiling hydrocarbons, or whether addition compounds are formed which subsequently decompose into lower and higher volatility hydrocarbons is not definitely known as yet. The most likely mechanism of formation is by way of addition compounds of the chlorides with the hydro-

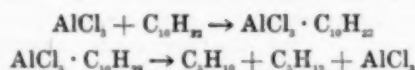
carbons of the starting oil. These addition compounds, not being stable at the temperature of the reaction, decompose into two or more compounds of the aliphatic group.

Perhaps the following hypothetical reactions will tend to make the addition and splitting off of the hydrocarbons clearer. In the kerosene oil, the paraffin hydrocarbons present are those with boiling points around Decane,¹⁰ Undecane, Tridecane, and higher molecular weight compounds. Let us take decane and undecane for our illustrative reaction of addition and decomposition:



In this assumed reaction the formation of hexane and pentadecane result with boiling points of 71 deg. C. and 270.5 deg. C. starting with decane B. P. 173 deg. C. and undecane 194.5 deg. C. Now in the reaction using the chloride of aluminium as catalyst, paraffins with boiling points around 71 deg. C. result when starting with an oil containing the compounds decane and undecane.

This illustration can be carried on so as to account for other hydrocarbons which are recovered in the gasoline. No unsaturated compounds were found in the gasoline fraction from the catalytic effect of passing hydrogen chloride over metallic aluminium. Unsaturation¹¹ was determined by absorption of the unsaturated compounds in sulphuric acid. The acid layer was water-white after shaking and allowing the two liquid layers to stand. But when chlorine was passed over the same metal, the gasoline fraction under similar treatment gave a deep reddish brown color in the acid layer, indicating clearly that unsaturated compounds resulted from this reaction. This brings us to the following hypothetical reaction of unsaturated compound formation:



The formation of amylene¹² and pentane would be indicated from this reaction. Gustavson's¹³ work is qualitative information in justification of the above assumed mechanism of reaction. He found that when a fraction of kerosene was treated with aluminium bromide and hydrogen bromide and then extracting the solution, the definite compound of aluminiumbromidebutylene $\text{AlBr}_3 \cdot \text{C}_4\text{H}_8$ was isolated.

SUMMARY

1. Three distinct methods for the conversion of heavy hydrocarbon oils into gasoline have been discussed. The single-phase gas system, the two-phase system of gas and liquid, and the three-phase system of gas, liquid and solid. The latter system has been treated in this paper.

2. Several hypothetical reactions have been shown to indicate the possible mechanism of reaction in the formation of low-boiling hydrocarbons from the action of aluminium chloride upon high-boiling point hydrocarbons.

3. The percentage of gasoline from kerosene due to the catalytic action of passing hydrogen chloride over the metals magnesium, zinc, sodium and aluminium gave the following results: magnesium 1.0 per cent, zinc 4.9 per cent, sodium 5.3 per cent, and 37.3 per cent for aluminium, all on the basis of the oil used.

4. The percentage yield of gasoline from kerosene due to the catalytic action of passing chlorine over the metals magnesium gave 0.3 per cent, aluminium 15.9

per cent, and for the non-metals silicon 0.6 per cent, sulphur 0.7 per cent, phosphorus 1.7 per cent, and selenium 5.3 per cent on the basis of the oil used.

5. The difference in the per cent of conversion to gasoline between the use of hydrogen chloride and chlorine upon magnesium and aluminium is marked. Hydrogen chloride upon aluminium gave 37.3 per cent yield, whereas chlorine, acting upon same metal, gave 15.9 per cent.

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Blast Furnace Irregularities and Their Treatment

BY J. E. JOHNSON, JR.

Regularity the First Requirement of Successful Operation

The keynote of successful operation of the blast furnace is regularity. I have tried in preceding chapters to make a picture of the delicate equilibrium which must be maintained between enormous forces, and I have tried to show that variations of only 1 or 2 per cent were enough to affect seriously the results of the operation, while a change of 5 or 6 per cent might be fatal.

The regularity required is of many kinds. First: uniformity of the stock charged; second: uniformity of its distribution into the furnace; third: uniformity of the blast in temperature and humidity; fourth: uniformity in the distribution of the blast in the furnace; fifth: uniformity in the quantity of blast blown per unit of time; sixth: uniformity in the kind of material to be produced. It may take days or even weeks to establish the absolute equilibrium which gives best results in cost, quality of product and output, and this cannot be secured at all except by regularity in all these factors. A temporary variation in only one of them may bring about conditions which will necessitate days of careful watching and adjusting in order to restore the furnace to the desired condition.

Undoubtedly the most important kind of regularity is that which leads to regular and uniform driving of the furnace, that is, to steady and continuous working. Many furnacemen have in times gone by followed the practice of tuning everything up for weeks and then making a sudden spurt in which gigantic outputs were secured generally, assisted by melting up a scrap accumulation of weeks, trusting that this spectacular performance would divert attention from the mediocre work which preceded, and the rotten conditions which followed the conclusion of such a spurt. But it is now well recognized not only by furnacemen but by managers that it is the long steady pull which counts rather than the spurt, and spurring for a record has very seriously declined in favor of the great benefit of the business.

The Furnace Plant Cannot Run Except When All Its Parts Run

The furnace plant is different from all other large plants in one particular. It has no reserves, no storage capacity, so to speak, at any point on the line so as to permit one part to run and store up a supply of its particular function that lasts while the function itself is suspended for repairs or the like. For instance, in the steel plant, not counting the mixer, since that may be classed with the bins of the furnace system, there is a storage interval of at least a few minutes before tapping, then after tapping the steel is poured into ingots and these are many hours in making the round trip,

¹⁰Landolt & Jahn, Z. Phys. Chem., 10, 303, 1892.

¹¹Egloff and Twomey, MET. AND CHEM. ENG., 14, 247, 1916.

¹²Work now going on in this laboratory for the isolation of unsaturated and saturated compounds from the cracking of petroleum, shows that amylenes and pentanes are readily formed from high molecular weight paraffin hydrocarbons.

¹³Chem. Zentr., 53, 12, 353, 1881.

though the actual time of pouring and stripping is but a small fraction of this. This means that there is a considerable volume in the ingot molds. Then there is storage again after the ingots are removed from the molds and put into the soaking pit, and so on, there being some storage capacity, be it great or small, in almost every part of the process, but in the blast furnace this condition does not exist. It is necessary that all the parts of the furnace operation be co-ordinated with one another in the closest possible way.

If the blowing engine stops the furnace stops instantly, and more than that, if the blowing engine stops without the furnace being flushed or cast the cinder is likely to fill the tuyeres which causes an enormous amount of labor for its removal and a delay of many hours. If the filling apparatus becomes deranged and the furnace can no longer be filled, it may be run for a short time, but if for more than an hour or two, even though filling be resumed at the end of that time, the stock filled immediately after the intermission is deprived of a considerable proportion of the time and exposure to the gas which it should receive, and reaches the hearth in a raw condition, deranging the work of the furnace. Consequently, if the filling arrangements become deranged to any considerable extent the furnace must be cast and the blast taken off. If the stop is to be a long one the tuyeres must be plugged up for reasons already pointed out. If, on the other hand, the arrangements for disposing the iron or the slag, particularly the former, become deranged, almost the worst condition of all arises, especially if the derangement is so great that the iron already in the furnace cannot be tapped out.

If it can be foreseen therefore that the iron cannot be taken care of as made, the furnace may be cast and shut down as before, but in none of these conditions is there any considerable margin of time, and it is true of the blast furnace as it is of no other industrial apparatus within my knowledge, that all the parts must function simultaneously, and stoppage of one stops all.

The Nature of the Irregularities

The variety of mishaps which can cause shutdowns of various kinds is almost infinite. They may be divided into two broad classes. First: those in which the derangement is of the furnace itself; second: those in which it is that of some of its secondary functions. That is to say, the furnace may be running beautifully, but a breakdown of the filling system shuts it down, or as was the most frequent cause of all within a few years, a breakdown of the blowing power stops it. These and all similar failures, external to the furnace itself, are more or less mechanical, and while plenty of them are serious enough and require enormous labor for their repair and cause great loss not only in the actual cost of the repairs themselves, but in the loss of time on the whole plant, they do not affect the furnace itself except as the result of a long stoppage, as has been described under that heading.

On account of the variety that is possible in such failures and the fact that the making of repairs in such cases does not differ from that of making similar mechanical repairs in other industries, I shall not attempt to describe them here.

Derangement of the Furnace Proper

With the other class of accidents or derangements those which affect the functioning of the furnace itself the conditions are very different. They are unlike anything else in industry, and the knowledge of how to handle them and restore the plant to operation would not be given by the most intimate acquaintance with all the other industries in the world. There are several degrees and varieties of these derangements, both

as to cause and as to effect produced. As to the causes the most frequent are, 1, heavy slipping; 2, internal explosions; 3, the breaking of a scaffold and the descent of the material which formed it into the hearth; 4, the cutting or bursting of a water-cooling member, such as a tuyere, cooler or cooling-plate; 5, breakouts; 6, a mistake in filling such as charging ore without sufficient fuel to take care of it.

The results of these various causes are, of course, very different when they are not serious, but strange as it may appear, when the results are serious they are practically always the same in a general way, though they vary infinitely in details. They are the chilling or partial chilling of the hearth of the furnace, so that the material can no longer be easily withdrawn in the molten condition; this causes the rest of the various conditions which follow. The reason for this is that a serious derangement from any of these causes brings about either the descent into the hearth of a large amount of insufficiently prepared material, or else a long stoppage of the furnace, which, occurring suddenly and without warning, means that no extra coke can be put into the hearth to meet it so that progressive freezing up occurs, its severity being proportional to the delay.

SLIPS

In the article on Mechanical Principles the actions which lead to sticking have been quoted from my paper, "Notes on the Physical Action of the Blast Furnace," and while the mechanism therein described may be subject to infinite variations of detail in that various circumstances affect and cause such sticking, the universal first remedy is the slacking of the blast so that reduced pressure below may cause the weight of the suspended material to bring it down. Slipping when almost continuous and not violent is spoken of as "sliding," and when even less violent, but still causing the excessive discharge of flue dust, as "dusting." I give below a further quotation from the same paper which covers both "kicking" or ordinary "slipping," and also those more violent accidents really deserving the name of explosions, which both in this country and others have, in some instances—fortunately only a few—resulted in bursting the furnace shell, or sometimes the bosh structure, with the violent ejection of the contents of the furnace.

EXPLOSIONS

"There come, however, occasionally, occurrences of this general type, but of so much greater violence and destructive effect than mere "slips" that they seem to require a further explanation.

This seems to be furnished by the fact that the conditions I have described may occur at any point in the furnace, and that the deeper they are the greater is the air-pressure, and also the weight of the ammunition in the air-gun thus formed; hence the greater the execution.

But if this occurrence take place so low in the furnace that the cavity formed reaches finally down to the tuyeres, a further condition arises, in which the cavity is filled not with gas but with air; and when the break in the obstruction comes, the incandescent carbon dust always present in the lower part of the furnace from the splitting up of the CO is precipitated (along with the other materials) into an atmosphere of compressed and heated air, giving precisely the conditions requisite to the production of an explosion of great violence, in which case the air-gun becomes a powder-gun, and is not infrequently burst by the charge. This accounts completely for the observed phenomena of these more violent occurrences.

As already explained, the "kicking" due to slips is

more violent and prolonged in proportion as the obstruction is deeper in the furnace. But there is still another reason for the shades of increasing violence, which make it almost impossible to tell where slips end and explosions begin; that is the varying quantity of unburnt air in the cavity above the tuyeres and the degree of its mixture with other gases. This is due to the gradual decrease in the depth of the layer of coke above the tuyeres. When this is no longer sufficient to burn all the oxygen to CO, CO₂ begins to appear, and when there is not enough to burn it all to this, free oxygen begins to appear, and its percentage thereafter steadily increases. It is evident that the precise point in this series of changes at which the slip takes place will influence profoundly the character of an explosion, and even the possibility of its occurrence."

One case is on record in Germany in which nothing but a stump of the furnace was left after the explosion. Another occurred soon after the introduction of Mesabi ores in the Shenango Valley, in which the furnace shell was completely wrecked. More recently at a furnace in the Pittsburgh district the bosh was torn wide open without a second's warning. The great steel bands around it, 10 in. by 1 1/4 in. and only about 1 ft. apart, were ripped in two as if they had been threads cut with a razor and almost the entire contents of the furnace were discharged through the great opening made, almost half the bosh wall being blown away.

These terrible accidents accompanied as they so often are by serious loss of life, each occur under different circumstances and with different results. Fortunately, they are too few in number to be classified broadly and accurately, but in general no two agree very closely. Many explanations have been given for each and every one, and a greater number of theoretical causes have been assigned for the production of the explosion which brings about such terrible results, but after careful consideration of them all I have been unable to find any cause as inherently probable, or with as few practical or theoretical objections as that advanced in the quotation just given.

Certainly if the fuel bed above the tuyeres burns down much below the top of the bosh while the balance of the stock stays suspended above it, we shall have a great cavity filled with an atmosphere containing free oxygen at a temperature well above 2500 deg. and under a pressure perhaps of 20 to 30 lb. If now we precipitate into this a great mass containing a large proportion of incandescent carbon in the condition of impalpable powder, what can we possibly have except a dust explosion under the conditions far more favorable to violence than those which have enabled such explosions to wreck coal mines, flour mills and other industrial operations almost without number?

Many other reactions have been proposed as the cause of these explosions, but not a single one that I have ever heard advanced will stand the test of representing the conditions truly and being at the same time chemically correct.

SCAFFOLDS

These can scarcely be treated separately from slips, since scaffolds are one of the most active causes promoting slips. Projecting out from the wall of the furnace they offer support to the charge column and in conjunction with the pressure of the blast from below they support its weight so completely that it ceases to descend until the blast is checked or some keystone of the crude arch formed dissolves away and the mass descends, causing a slip.

Scaffolds are of many and various kinds. It is probable that a large volume could be written concerning this subject alone had anyone the patience to collect all

the data available. In general, however, scaffolds confine themselves to the region from the top of the pasty zone downward. Some furnaces which work "tight" are said to have dust scaffolds, but I have always preferred to believe that this was a condition of tightness at a certain zone due to the continuous redeposition in that zone of carbon dissolved at a lower level, according to an action earlier described.

Leaving these we have only to deal with scaffolds formed of molten or semi-molten material. They may be a foot or two thick radially or they may form a complete floor across the furnace. Of the latter I have heard several times, but fortunately I have never seen myself. The blast furnace is understood so much better now that those occasions are becoming very rare if they have not gone forever. But scaffolds from a foot to several feet in thickness are still not uncommon; in plan they may extend from a bare lump on the side of the furnace to a complete ring all around it, almost as regular as if it had been built on purpose.

In regard to the latter I can speak with certainty for I have had the unusual experience of seeing such a scaffold in a "live" furnace, just after it had caused its victim to undergo one of the explosions which I have just described, and to throw out its entire contents to a point well below the scaffold. It was an experience that I shall never forget. I was at the time on the upper platform of a steeple-type blowing engine, which was running along quietly enough when suddenly something happened which I have never been able to compare to anything except the blow which an unsuspecting man might receive from a blackjack; he would be knocked to his knees for a moment and then get up and run away. The blowing engine seemed to receive just such a shock, and after a few seconds went on much more easily than before the shock had occurred.

A prolonged roar and a lively fusilade on the engine-house roof announced that something out of the common had happened. On going out to investigate I found that a real explosion had taken place and the furnace top was evidently completely deranged. The furnace was cast and stopped as soon as possible, and when we were able to reach the top we found the bell resting securely in the hopper on top of the lip ring instead of beneath it.

Investigation showed that it had been driven upwards with such force as to break the lip ring in two and force it up in the hopper until the bell could pass through it, then the lip ring dropped back to its seat with the bell on top of it. The enormous bell beam built up of heavy plates and angles was bent at a sharp angle, though the forces required to do this must have reached hundreds of tons. Other things were about in a similar condition.

After the top was cleaned off and cooled down enough to work two of us finally ventured to lean over far enough to look down inside; as several hours had passed all was then quiet and we could see a dull red "ring" scaffold running all around the furnace at a height that seemed up somewhere above the top of the bosh, and seemed to extend out some 3 ft. all around. As the furnace was 21 ft. in diameter this would have left a 15-ft. hole through the center. It may even be that the scaffold was greater and the hole smaller than this.

I take this case to be almost ideal proof of the accuracy of the theory of explosions described in the last section. The whole charge column taking advantage of some accidental variation, high pressure or the like, evidently came to rest on the top of the scaffold, and being at the top of the pasty zone it held there while the lower portion settled as the coke burned away. In a comparatively short time, two or three hours at the

most, the surface of the lower portion descended well below the top of the bosh and the height of the fuel bed was no longer sufficient to prevent the presence of some free oxygen in the space above it. Finally something happened to precipitate the suspended mass above through the central hole in the scaffold and the explosion, which I have so inadequately described, instantly followed.

It is easy to see that a ring scaffold of this kind is the most dangerous that we can have, in spite of its symmetry, because it furnishes such ideal support for the charge column and tends to stop the descent of the latter so completely. A scaffold on one side only tends to check the material on that side and to force the fines over to the far side of the furnace, the lumps running back under it. This produces a very uneven descent of the charge into the hearth and a highly improper distribution of the gas current through the descending charge, but this, though bad enough, is obviously not so serious as the complete suspension of the charge with results like those above described.

THE REMOVAL OF SCAFFOLDS

This is a subject concerning which we know far less than we should. Many furnaces which once become scaffolded never work satisfactorily again during that blast, while again others may get rid of the trouble completely and do as good work after as before. In general, there are three methods to be pursued. First: to restore conditions as nearly to normal as possible, running with a comparatively light burden and hoping to melt or wear the scaffold away whatever its position. Second: by careful watching of the working of the different tuyeres to try and locate the position of the scaffold and then try so to direct the filling as to overcome as far as possible its bad effects, or by directing the action of the furnace violently against it to wear it away. Third: by deliberately sacrificing the work of the furnace for a day or two, putting in a light burden with a considerable excess of whatever material will produce the most fusible slag, generally silica with a coke furnace, although silica and fluorspar would be better, lime and fluorspar for a charcoal furnace and by extra heat and dissolving action scour it bodily off.

In the case of a coke furnace I have known the ore burden to be almost entirely replaced by a great quantity of sand. Coke-furnace accretions always contain a considerable quantity of lime, as already pointed out, so when this great quantity of unfluxed silica reaches these accretions in the presence of a great excess of fuel to produce all the heat necessary, it at once tries to satisfy itself with bases by dissolving away the accretion. I have never tried this drastic remedy myself.

On the other hand, charcoal furnaces, especially when they are run on very lean slags, build up on the walls with that fusible but tough and stringy material. These slags are decidedly on the silica side of the most fusible slag, and by lightening the burden and adding an excess of lime for a day or two they may generally be scoured off completely. This I have done more than once.

THE DESCENT OF UNREDUCED MATERIAL INTO THE HEARTH

Obviously every time the furnace hangs and then slips we have a condition which deprives a part of the material of some of the time which it should have had for preparation in its descent through the furnace. But in the upper part of the shaft where we have the greatest surplus of heat and in general a surplus of reducing power, such a slip is not of much consequence unless it represents hanging for the space of an hour or more.

But as we go further down into the furnace the mar-

gins of heat and of reducing power are lower and lower, and the time in which to make up for treatment lost is smaller and smaller, so slips become not only more violent because of the higher pressure from which the furnace is relieved, but more serious, and their effect on the action in the hearth may be disastrous, especially if the shaking up which occurs at that time permits the ore to run ahead of the coke and come down into the hearth before the coke which should accompany it.

Obviously in this case we have material very inadequately prepared in the first place, and yet have no coke appropriated, so to say, to the purpose of finishing the smelting action of the furnace upon it, let alone supplying any deficiencies in reduction. The same is true in the case of the breaking off of a scaffold and the descent of its material into the hearth.

The Chilling of the Furnace

In all cases of chilling of the furnace we have an action which is serious in proportion to the amount of incompletely prepared material involved.

If this be small it may be taken up by that latent reserve of heat which the furnace seems to possess, without producing a very serious result. But a very moderate amount of material so precipitated into the hearth brings about a complete derangement, first: the incomplete reduction of the iron which passes into the cinder, turning it as black as tar; second: the cooling of the hearth with its resulting insufficient desulphurization and the ruin of whatever iron may be produced in consequence; third: insufficient heating of the slag and iron to permit their discharge from the furnace through the normal apertures in the proper way. Finally, the chilling of a heavy scull of iron, frequently low in carbon, around the whole interior of the hearth and the lower part of the bosh, making the task of drilling in to discharge either iron or cinder very difficult. This is quickly followed by the freezing of the iron in the lower part of the hearth so completely that it will not run no matter how far we may drill into the tapping hole, which is then "lost." This in turn is followed by the freezing up of the iron and cinder around the tuyeres until perhaps only one or two are left sufficiently open for a little blast to pass through. Meantime it having been impossible to withdraw anything from the furnace, and some blast going in continually, combustion continues and more slag continues to be formed, and in the greater quantity because a great percentage of all the iron also passes into it.

We have now a furnace containing many tons of molten material to a height perhaps several feet above the tuyeres, the bottom of the hearth solid with frozen iron in its toughest condition, and a scull of iron or steel all around the upper part of the hearth and the lower part of the bosh, which prevents our making any opening at the cinder notch for the withdrawal of the cinder which has accumulated. We know that we cannot go on indefinitely, that, for instance, the liquid pressure of the thin, violently active, scouring cinder inside the furnace increases the liability of its breaking out at some point, and the certainty that when it does so the running stream will cut almost anything that comes into its path, will run all over the ground and make access to the aperture almost impossible, and that if the engine fails this huge mass of slag will seek its own level in the penstocks and bustle pipe, and that if on top of present misery a slip occurs it will force the slag into the blow pipes and penstocks, even against the blast pressure.

When this condition is reached the furnace is technically said to be "in a mess." Any furnaceman who has ever passed through the experience will admit that

the term is literally as well as technically correct. If he be consulted at the time he will probably express an unfavorable opinion of a man with so little judgment as to enter a business capable of producing such horrible conditions.

These are also the conditions in a general way which result from other causes, a long stop without warning, a mistake in the filling by charging too little coke, a bad breakout followed by water running from the ditch through the hole made by the breakout into the hearth and standing there for hours because the breakout had effectually dammed the ditch, which I once experienced, and various others.

The question is what course must be pursued to restore those normal conditions which bring profit to the owner and comparative peace of mind to the operator and the crew.

A little consideration shows that no matter what the ultimate cause may have been, the immediate cause of the difficulty is the absence of sufficient heat to bring the materials in the hearth to the temperature at which they will run out, and if my description of the terrors of such a condition were adequate (which it is not), it would perhaps explain my tiresome insistence in earlier chapters on the free-running point as the critical temperature of the furnace and on the vital necessity of enough heat in the hearth to bring about this temperature.

The remedy is then to introduce more heat into the hearth. But our chief method of doing this is to introduce more fuel and we can in general only introduce this at the top of the furnace, and in order to permit its descent into the hearth all the charge in the furnace at the beginning of the trouble must be worked out. This requires from eight to twenty hours, depending on the rate of driving, even in normal operation, when all the molten material can be removed as formed, in a truly liquid condition; but when the furnace is in a "mess" the possibility of such regular removal has vanished, in fact, we might define a mess as any condition which made the free and regular removal of the molten material impossible.

We must then find means to carry on such removal as best we may until the blank of coke charged to give relief can reach the tuyeres, and this period is prolonged just about in proportion to the difficulty of slag and iron removal. For this reason the wise furnaceman when he sees signs of impending trouble, charges a good blank of coke knowing that even if it does not reach the hearth in time to avert serious trouble it will shorten by so much the weary interval of difficult and irregular flushing and casting.

If the mess arises through a breakout or mechanical breakdown, which causes a long and utterly unexpected stop, he charges the blank the first thing on starting up, and if the difficulty threatens to be a serious one he lightens the burden to a material extent so as to have a reserve of heat to overcome the irregular conditions which will probably persist long after the blank is gone and the furnace once more in operation.

Steps to Be Taken in the Early Stages of Chilling

The important question is, "What methods are to be used to remove the slag and iron after the regular methods fail?"

As the furnace loses its normal supply of hearth heat, the portion farthest from the tuyeres naturally feels the loss first and therefore the iron in the bottom of the hearth, where the regular tapping hole is, freezes so that no iron can be drawn from it; sometimes the drill simply encounters a mass of red hot tough pasty iron which it cannot penetrate, more rarely it goes half

across the furnace underneath the iron in a mass of brick, slag and heterogeneous material which can be drilled but which will neither run nor allow the iron to run.

In such a case the molten iron lies higher up and ordinarily other holes are drilled at successively higher levels until liquid iron is reached or it is found impossible to reach it.

In some rare cases a dry hole under the bottom of the scull in the hearth may be shot with dynamite and the scull broken through up into live iron above, which will then flow out. It must be remembered that the hole is between red and white hot and the radiation from it is sufficient to set off the dynamite in a few seconds so this operation is not to be regarded as a safe and harmless pastime. On the only occasion when I used this expedient the hole was drilled well back to the center of the furnace, so there was no danger of damage to the hearth jacket as there would be with a shallow hole; the dynamite was wrapped in rags soaked in thick grout and laid on a little wooden trough or boat so as to keep it from contact with the bottom of the hole; the fuse was cut to burn only a few seconds, it was lit after the charge was placed in the trough and the latter was quickly pushed down to the end of the hole with a long rod and all hands retired to a short distance without unnecessary delay, and waited until the explosion came. This was followed by a small river of iron and our troubles were over for that time.

Generally, however, no hole can be drilled at all at the bottom and it becomes necessary to go higher and higher to reach the iron. When the top of the iron notch opening through the hearth jacket is reached and still the scull around the hearth cannot be penetrated the tapping hole is "lost" and it is then necessary to go to the cinder notch.

Casting Through the Cinder Notch

The construction of the latter is excellently designed for the purpose for which it is normally used, the quick, easy and safe removal of the cinder. But while water-cooled bronze will withstand molten cinder of almost any temperature, it will not withstand molten iron at all, or, at least, it is likely to fail in a few seconds under a flow of iron, especially the raw, scouring and extremely corrosive material which is produced at such times.

The failure of the water-cooled bronze parts is certain to result in a violent explosion, and therefore before casting through the cinder notch the bronze cinder cooler must be removed. The monkey will probably have been "pulled" already on account of stiff, sluggish slag. If there be an outside iron cinder cooler it must take its chances because it cannot be "pulled." The danger of having this cut is much smaller, and bad explosions are not so likely to follow if it is, and whatever risk there may be is further reduced by making up a bed of sand or clay in the bottom of it. An emergency runner of sand is built from the cinder notch back into the iron trough if possible or else to the iron ladles or the pig beds.

One disagreeable consequence of casting through the cinder notch is that the iron cinder cooler, if there be one, or if not the brick surrounding the hole, are cut and roughened by the scouring mixture of iron and cinder, which is always to be expected under such conditions, and lumps of iron or cinder are left burnt onto the brick or the iron cooler as the case may be. The temporary bottom of sand brick or clay used to pave the bottom of the opening helps to prevent this, but the lining is likely to be knocked off, particularly on the side. These lumps are very difficult to remove when they do

become burnt on and unless they are removed the bronze cooler cannot be put back to its proper place. They are, therefore, very objectionable.

In order to protect the hole completely, I have used very successfully the expedient of inserting a piece of common wrought-steel pipe about the size of the inside of the bronze cooler and packing around the outside of it with clay. The pipe may burn up during the first cast through it, but usually lasts several. When burnt up it can readily be replaced, and when normal conditions are restored it can be pulled out and the clay packing of the pipe removed without difficulty, leaving the brickwork or the iron cooler, as the case may be, in perfect condition. This is a small matter, but it may save hours of work and injurious delay in getting back to normal operations.

When all the necessary arrangements have been made the next thing is to drill through the cinder notch if possible. When this can be done the furnace can be kept in fairly steady operation and the life-saving blank worked down to the tuyeres without undue delay, and the trouble is then likely to be pretty well over.

Opening a Chilled Hearth

But if the scull is too hard to drill and too rough to drive—then the real trouble begins. To force an opening we have now available four means, dynamite, the kerosene blowpipe, the electric arc and the oxygen burner.

DYNAMITE

If the hole has been drilled back well into the scull so that the latter shows red hot, then the hole can some-

times be shot open with dynamite. The charge should be made up in a cartridge made of a piece of pipe 2 in. or 3 in. in diameter and mounted on the end of a long piece of small pipe for a handle so that it can be set off instantly when the cartridge has been placed in the hole. This latter is not a particularly pleasant job because the dynamite may be exploded prematurely by the heat of the hole. There is, of course, no time for tamping and much of the force of the shot is lost, but by following up with larger cartridges as the hole swells the scull can sometimes be torn open.

I once saved by this means a furnace which had lost not only the tapping hole and the cinder notch, but also all the tuyeres but two. We shot open a "dead" tuyere, into which we had drilled as far as we could in trying to flush through that, its level was too high to give good drainage from the other tuyeres, but opening it removed a huge mass of molten and pasty material which had been held up in the bosh by the blast pressure. This gave us time to take further steps and really saved the day.

The closing of this hole was no joke; the drainage afforded was incomplete because only on a level with the tuyeres, so if the blast were taken clear off the cinder came back into our only two remaining tuyeres. Of course, with the blast on even very little the big hole which the destruction of the tuyere had left, discharged flame and shot cinder about like a small bessemer converter. We finally checked the blast with the snort valve to the point where the cinder was barely kept out of the tuyeres and reduced the discharge of flame and shot cinder to the point where one of our

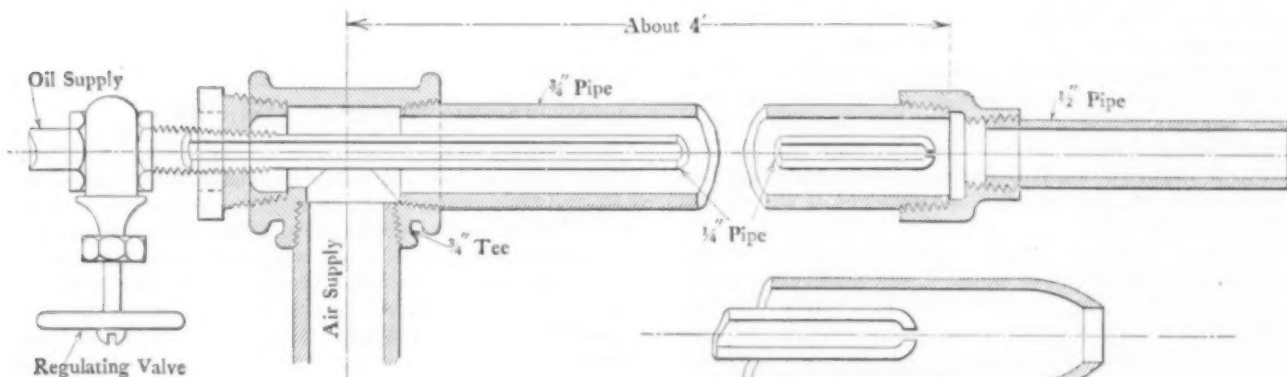


FIG. 1 - First and Correct Construction of Burner

FIG. 2 - First Improvement (?) Value Minus 50%

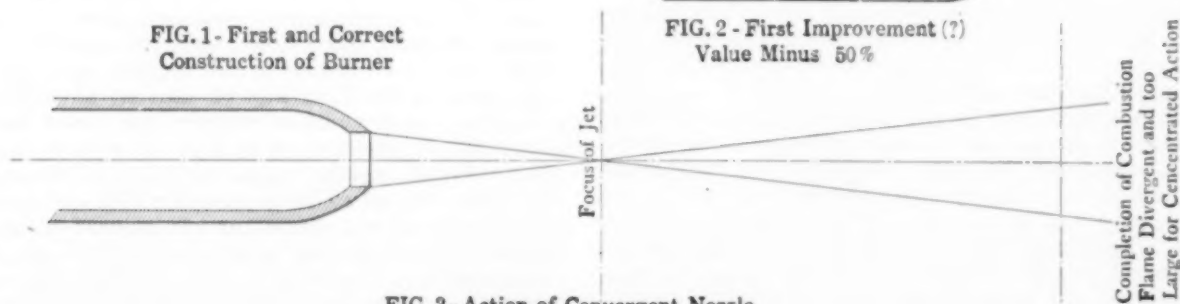


FIG. 3 - Action of Convergent Nozzle

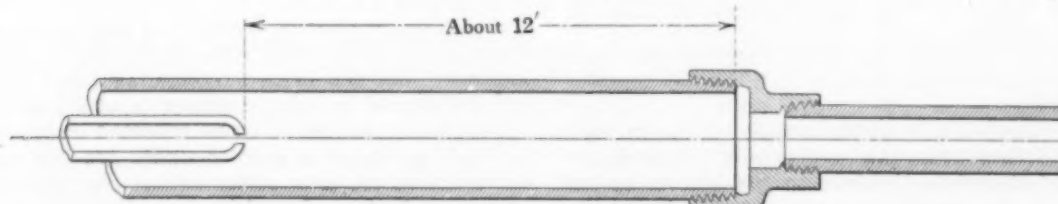


FIG. 4 - Second Improvement (?) Value Minus 100%
EXPERIMENTS WITH OIL BURNERS

keepers volunteered to stop the hole, which he did with clay balls and a stopping hook. The job only took two or three minutes, but his overalls were practically burnt off him by cinder shot when he finished; it was one of the pluckiest acts I ever saw. Such details will perhaps help to give some idea of the conditions likely to arise during a mess.

The conditions under which dynamite can be used successfully are rare and its use is always highly undesirable because of dangers to which its use exposes the plant as well as the crew, and in consequence it is not often used.

THE KEROSENE BURNER

Probably the first means developed for meeting these conditions was the kerosene blow-pipe. Its use gives such very different results, according to its control, that it has been utterly condemned by some good furnacemen, while it was regarded as a life saver by others, before better means took its place.

Some experience with these blow-pipes and some of the principles on which their successful use depends were described in the *American Machinist* ten or twelve years ago and a portion of the article is quoted here.

The oil burners shown in Figs. 1, 2, 3 and 4 were made in great haste and in almost total ignorance of the details of their construction, as far as experience was concerned. A piece of $\frac{1}{4}$ -in. pipe was welded shut on one end and a $\frac{1}{16}$ -in. hole drilled through this end. On the other end of this pipe a long thread was cut, which was screwed into a bushing, filling the rear end of a $\frac{3}{4}$ -in. T. At the side of the $\frac{3}{4}$ -in. T the air entered through a nipple and hose. The $\frac{3}{4}$ -in. pipe in the front end of the T in the first burner made was about the same length as the $\frac{1}{4}$ -in. pipe inside (about 4 ft. long), and on its end was screwed a reducer, into the end of which a $\frac{1}{2}$ -in. nipple, about 4 in. long, was screwed.

This burner was very successful, though used under lighter air pressures than those we subsequently obtained, but having been the first one made, it was, perhaps, natural to think that subsequent ones should be better; so desiring another, the $\frac{3}{4}$ -in. pipe was drawn down by a smith to a conical end or jet much better looking than the reducer and $\frac{1}{2}$ -in. nipple, as shown in Fig. 2. But after full and fair trial, it was found impossible to get the concentration of heat in one place with this that was obtained with the other, for the reason that under the heavy pressure of air the velocity of efflux was so great that combustion was not complete until a point was reached something like $1\frac{1}{2}$ ft. beyond the end of the burner. With the conical nozzle the jet action had ceased, and the lines of flow of the flame had ceased to be convergent and had become divergent within less than a foot; consequently, the flame was without any accurate center, and was quite rapidly divergent at the point where combustion was complete and where the greatest heat should have been if it had been properly concentrated, all as shown by Fig. 3.

The $\frac{1}{2}$ -in. nozzle by permitting the flow to be approximately parallel, enabled the combustion to be complete within a small area at whatever distance from the burner might be necessary within reasonable limits, and, therefore, focused the activity of the flame much better than the convergent nozzle. This, at least, seemed to be the theory, and these certainly were the facts, as was clearly proven by cutting off the convergent nozzle and substituting for it the reducer and $\frac{1}{2}$ -in. nipple.

Another improvement, shown in Fig. 4, was attempted, with the object of heating the oil further by the action of the $\frac{3}{4}$ -in. pipe upon it before it reached the point of discharge. It should have been stated above that the oil was delivered by pipe and hose connection

from a barrel placed at the top of the furnace, some 70 ft. above, so that there was a very good head to drive it through the $\frac{1}{16}$ -in. hole, and a sufficient quantity emerged to make a very large flame. The quantity was regulated by a $\frac{1}{4}$ -in. globe valve on the projecting end of the $\frac{1}{4}$ -in. pipe, at whose inner end was the $\frac{1}{16}$ -in. orifice. The operator regulated the action of the blow-pipe by opening or closing this valve minute amounts to suit conditions, and also fed the nozzle or drew it back so as to keep the hottest part of the flame in the point where the melting was desired to take place. The improvement, which was attempted, consisted in cutting off the $\frac{1}{4}$ -in. pipe which carried the oil about 1 ft., so that the oil had to traverse about a foot of space through the $\frac{3}{4}$ -in. pipe before reaching the $\frac{1}{2}$ -in. nozzle, the idea being that it would in this way be preheated more than by simply passing through the $\frac{1}{4}$ -in. pipe for the same distance.

The attempt to operate this burner was most exasperating and unsatisfactory. If the valve were regulated to bring the flame to the right condition, it would sustain itself for a brief instant, go out, and be followed by a surplus of oil which re-ignited against the hot surface and made a detonating mixture with the air with which it had become mixed during the instant of extinction, so that virtually the action of the burner was no more than a series of sharp explosions at intervals of about a second, with, of course, no useful heating effect.

No regulating of the valve sufficed to cure this most objectionable condition, but finally close observation showed that coincidentally with the flashes of re-ignition there came a few drops of oil in liquid form, not spray, from the end of the $\frac{1}{2}$ -in. nipple. It was these which supplied the excess of combustible and made the smoky flame accompanying the explosions (which, of course, were perfectly harmless in their nature).

When this was seen the secret was out. The oil was not driven with sufficient force to throw it entirely into spray at the base of the $\frac{1}{2}$ -in. nozzle, but some of it ran down and along the bottom of the $\frac{3}{4}$ -in. pipe, whence it was picked up and carried in waves by the action so familiar to all in such cases, with the result that there was first an excess and then a deficiency of fuel for the air, the supply of which was constant.

A longer $\frac{1}{4}$ -in. oil pipe was at once procured, which delivered the oil just at the base of the $\frac{1}{2}$ -in. nozzle, where the high velocity of the air consequent on the reduction of area caught it and threw it into a perfect spray, so that the action was complete and continuous. This perhaps may be a useful experience for those who have to do with oil burners as a regular occupation.

Another point of much interest in connection with these oil burners came to light during the brief experience, of which mention has been made. This was that the burner did better the deeper the hole in which it was working. The reason was not very far to seek. When the hole was quite deep, say 2 ft., and of comparatively small diameter, the flame which, had it been unobstructed, would have gone perhaps 7 or 8 ft. beyond the end of the burner, was compelled, by striking the object of its attack, to return on its course and come back over the burner itself. The result would have been that the burner would have been heated to a white heat in a very few minutes had it been a piece of "dead" pipe of the same size in the same flame, but as a matter of fact the burners never showed the least inclination to get even red hot, being cooled by the rapid current of air through them. The other phase of this fact is that the air must have been heated before leaving the burner to a very considerable degree. One could even imagine that it may have been 500 or 600 deg. Fahr., though

naturally no effort was made to determine the amount at that time.

Just what the flame temperature in such a case is I do not know. Theoretically, it would probably be 3500 deg., or perhaps more, but actually would not likely be above 3000 deg. If, now, the fusion point of the substance to be melted were 2500 deg., then an increase of 500 deg. in the temperature of the air, giving an increased flame temperature of perhaps 400 deg., would make the latter 3400 deg. instead of 3000 deg.; and while this is not a very great difference absolutely or relatively, based on the total temperature, when compared with the fusion temperature (assumed to be 2500 deg.), it is seen to be almost twice as great a difference, implying twice as much heat available for melting operations, as well as nearly twice the "thermal head" for causing the heat to flow from the flame to the object being melted. Moreover, it is almost certain that the oil inside of the $\frac{1}{4}$ -in. pipe was somewhat preheated also, and, therefore, its vaporization at its exit from this pipe was much quicker and more complete.

Much larger oil burners are sometimes used, in some cases a 2-in. pipe for air and a $\frac{1}{2}$ -in. pipe for oil, and in some cases no nozzle is used because it melts away in the intense heat developed, the pipes simply discharging through their open ends.

The necessity of having the focus of the jet coincide with the zone of complete combustion has been shown by all my observations, and it is this fact which makes it so difficult to secure the best results with these burners, because we have four variables to regulate; the distance of the nozzle from the surface to be fused, the velocity of the jet depending on the pressure of the air at the nozzle, and the quantity of air depending on the size of the pipe as well as the pressure, and the quantity of oil.

The fact that the volume of air and its velocity which should vary independently, must actually vary simultaneously, is perhaps one of the greatest difficulties. Sometimes it seems impossible for one man to obtain a satisfactory adjustment of all these variables when another will have no difficulty. On one occasion my assistant, the master mechanic, and I all failed to do any good with one of these burners, but the colored pipe fitter came along and did good work with it.

One vital fact to remember is that the best fuel for generating heat to melt iron is the iron itself, not only because of the heat it develops, but because the iron oxide slag formed as a result melts at a much lower temperature than iron. For this reason no burner ever works successfully except with an oxidizing flame. A reducing flame makes a pretty sight and a lot of light, but does no good whatever, whereas an oxidizing flame, making a hideous roar and showing only a short blue flame, will really cut. After the point of attack is heated to the proper temperature the supply of oil should be reduced to the minimum so as to leave as much oxygen as possible free to burn the iron.

Later and far better methods of burning open-chilled top cinder notches and the like have laid the kerosene burner on the shelf for most conditions, but for isolated plants caught in a mess without the modern apparatus they are not to be despised.

THE ELECTRIC ARC

Heat developed by electricity differs in one important respect from heat developed by combustion. Its temperature of application is virtually unlimited, from the industrial point of view at least, while we have seen the rapid increase in limitation to combustion heat, which rise of temperature causes. Electric heat has then an increasing advantage as the temperature of application

rises and this is, of course, greater in fields where the actual amount of heat required is small.

These conditions are exactly those of melting out a frozen cinder notch or tapping hole.

Nearly all blast furnace plants of importance have an electric plant of some size and very early in the present century it was found that the electric arc could be used in such cases with tremendous advantage, and the practice rapidly spread.

The chief consideration next to having sufficient energy available is that the voltage shall be low. In the description of the removal of the salamander in a previous article, the reasons for this are given and need not be repeated here. The voltage preferred for this service is about 50 and at least 1000 amperes should be at hand. Twice as much is better. This gives a short controllable arc and the melting can be done where it is needed.

Alternating current has the great advantage for this service that the approximate voltage needed can be obtained directly from suitable transformer, whereas direct current must be choked down in voltage through a water rheostat or some equivalent. This is not only wasteful of power, but the apparatus is clumsy and the control not easy. At one large plant a transformer of suitable size and design was located permanently at each furnace so that it was only necessary to place the carbon and turn on the current. A hole can be burnt in a short time into any place where there is enough conductivity to carry the current.

THE OXYGEN BURNER

Modern progress has brought into common use the oxyhydrogen and oxyacetylene blow pipe and developed comparatively cheap methods of producing the gases so that the use of these means for cutting iron and steel as well as that of oxyacetylene for welding is growing at an exceedingly rapid rate. Carloads of oxygen cylinders are now more common than single ones were not long ago. The application of this apparatus to frozen cinder notches, etc., was obvious, and it has now come commonly to be preferred to the arc, although the latter continues to be used.

The preferred practice is to use the blow pipe only to bring the surface to be burned up to the temperature at which it will burn in pure oxygen and then direct a stream of the latter against it under heavy pressure. The reflex velocity of the jet keeps the hole clear of the burnt iron formed and rapid action is maintained.

The results which can be obtained in this way are little short of marvelous, instead of being a matter of hours to burn through a few inches of iron as is the case with the oil burner, it is a matter of a very few minutes. In one case of which I knew, a badly frozen tapping hole was burned through and the iron running in about 6 minutes from the time the oxygen jet was turned on. With the great increase in the ease of obtaining oxygen quickly and cheaply, this process seems likely to supersede all the others. It and the electric burner together have done much to remove the terrors which a chilled furnace formerly held for the unfortunate furnaceman.

ADDING ADDITIONAL FUEL IN THE HEARTH

In the most extreme cases of chilled furnaces the material in the hearth is so chilled that the blast has but little effect, in fact, can practically not penetrate the frozen material enough to generate any heat or form any slag. In such cases the materials in the hearth are dry rather than pasty, and can be removed through the tuyeres and cinder notch by pulling out solid lumps of coke, ore and limestone.

In such cases the preferred procedure is to dig a considerable hole into the cinder notch and into the tuyere nearest to it, fill up this space with fresh lumps of coke put in from the outside, then put back the blow pipe into the tuyere. If necessary, kindling or a piece of waste is used to ignite the coke as in blowing in.

A small quantity of blast is then put on; this passes through the coke and burns out the cinder notch, thereby establishing good communication between these two and enlarging the cavity. The furnace is then stopped and the next tuyere is then treated in the same way, and by blowing through this communication from it also is established with the cinder notch. In this way, if need be, one tuyere after another can have re-established its communication with the others and with the cinder notch, while much heat is added by the combustion of the coke put into the tuyeres.

Personally, I have never had to fight a furnace that was so badly bunged up as this, but the process has been used by experienced furnacemen who have described it to me.

Another expedient which is well recommended by those who have used it but which I have never tried, is the use of kerosene in the tuyere itself.

A small pipe is put through the peep-hole in the elbow of the penstock and run practically to the inner end of the tuyere. This is supplied with kerosene under pressure from a tank above and the blast turned on. This converts the whole tuyere into a gigantic blow pipe and permits imparting to the furnace a great amount of heat at the point where it is most needed. In this case also, if the bosh is too completely chilled to permit of passage of gas formed an outlet must be made through the cinder notch or perhaps through another tuyere, as in the previous case.

The details of these operations necessarily vary almost infinitely according to the judgment of the operator and conditions to be met. It is therefore impossible to describe them in detail, but the general outline of the operations is as described.

A Method of Exhibiting the Velocity of Iodine Ions in Solution *

BY S. W. J. SMITH

The apparatus is represented in the diagram. The containing vessel is a U-tube with widened ends as shown. The diameter of the tube may be about 0.5 cm. or less. The cross-section of the tube should be fairly uniform. Either 25 cm. or 50 cm. is a convenient (total) length for the tube if it is desired to use it in connection with an ordinary lighting-circuit voltage of 100, or thereabouts, and to obtain a rapid estimate of the velocity of the ions. The electrodes (at A and B) are, preferably, of platinum foil. The liquids used are equally concentrated solutions, containing—e.g., either 0.2 gm. or 0.1 gm. mol. per liter of potassium chloride and potassium iodide respectively. The novelty of the experiment lies in the method of exhibiting the line of separation between the solutions. For this purpose a small quantity of mercuric chloride (corrosive sublimate) is dissolved along with the KCl. In the endeavor to main-

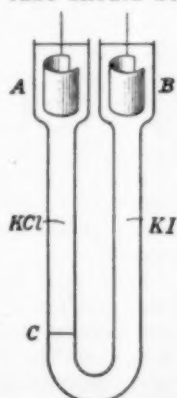


FIG. 1—ARRANGEMENT OF APPARATUS

tain symmetry an equal quantity of the same salt may be added to the KI.

In this case a thick yellow disc of mercuric iodide, precipitated by the action of the KI upon the $HgCl_2$ contained by the KCl, will appear at the junction between the electrolytes.

The electrodes at A and B are connected to the source of supply, that at A being made the anode. The boundary at C immediately begins to move upwards. It travels as an extremely thin horizontal disc, which can be located very accurately and projected with ease. And the disc will move at speeds of the order of 1 mm. per minute, so that its motion can be followed without difficulty by a large audience, and an approximate estimate of its velocity can be obtained in a few minutes.

A table giving the results of an experiment then follows, and it is remarked that the possibility of observing the reverse motion of the ions is due to the yellow coloration produced by chlorine ions which decompose a fraction of KI.

The solution contained 0.2 gm. mol. per liter. In an experiment made to obtain an estimate of velocity under the potential gradient of 1 volt per centimeter at a definite temperature, the distance traversed by the line of separation during the first half hour of the experiment (measured by means of a small cathetometer) was 4.13 cm. The distance traversed in the second half hour was 4.53 cm. The difference was probably due mainly to a higher mean temperature in the second half of the experiment. On this occasion an ammeter was included in the circuit. The reading rose slowly during the observations. Its mean value during the hour was 0.02 ampere. The specific resistance of the electrolytes was measured at 10 deg. C. (the temperature of the room) just before the tube was filled. The mean value was approximately 55 cm. ohms. The value of the current immediately after the circuit was completed was 0.023 ampere. The area of cross-section of the tube was about 0.31 sq. cm. Hence the initial potential gradient in the tube was approximately 4.1 volts per centimeter, and the velocity of the anions, iodine and chlorine, as determined in this way, is about 0.00059 at 25 deg. C. in cm. per sec. per volt per cm. If accurate and not rapid determinations were required much smaller potential gradients could be employed.

The author concludes by referring to the solutions used, and their conductivities and concentrations. It is also mentioned that a small quantity of $AgNO_3$ might be added to the KCl solution, and redissolving the precipitate by NH_4OH . The AgI formed during the experiment being insoluble in NH_4OH then acts as an indicator, and the progress of the ions may be watched as before. It is found, however, that this method is not so satisfactory as the one mentioned above.

Future Rubber Output.—From a statement issued by the B. F. Goodrich Co., Akron, Ohio, the prospective rubber output is as follows for years up to 1921. Past production back to 1905 is also given.

	Plantation Tons	Native Tons	Total Tons
1905	145	60,800	60,945
1907	1,000	68,000	69,000
1909	3,600	65,400	69,000
1911	14,100	61,900	76,000
1914	64,000	60,000	124,000
Estimated Production After 1914			
1917	147,000	34,500	181,500
1919	183,000	30,000	213,000
1921	209,000	30,000	239,000

The significant feature of this table is the greatly increased growth of cultivated rubber on plantations.

*An abstract of a paper read before the Physical Society of London. From *London Electrician*, May 26, 1916, p. 255.

Ethyl Alcohol from Wood

The Process, Its Development and Requirements

BY F. W. KRESSMANN

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Madison, Wis.

The European war has caused a large number of industrial changes in this country in the last year. Many industries which several years ago were in a depressed condition are now operating at capacity and in many the capacity is being increased as rapidly as building operations and manufacturing of apparatus will permit.

The alcohol producers of the country have felt this change. The ethyl alcohol or industrial distillers had felt the prohibition movement and the wood alcohol market was barely holding its own because of the generally depressed condition of the hardwood destructive distillation industry, especially the acetate of lime end of it.

Now all this is changed, the ethyl alcohol business is enjoying an unprecedented prosperity and many old distilleries that had not operated in years are working at full capacity and several very large new distilleries have been built. In fact, the industry was contracted up to such an extent that an order for 2,000,000 gallons of 95 per cent alcohol for immediate regular delivery went begging for some time.

Because of this greatly enhanced value of alcohol for war purposes and because of the tremendous and alarming increase in the cost of gasoline, the production of ethyl (grain) alcohol from wood should receive the undivided attention of the large sawmill operators and other producers of wood waste. For this reason a brief history of the production of ethyl alcohol from wood, especially as the process has been developed in this country, along with a description of the process, plant requirement, and estimated cost of production, we believe, will be of particular interest at the present time.

For, in addition to the foregoing factors, a number of others may be mentioned that would operate in favor of wood as against grain and molasses for the production of alcohol. The war, of course, has increased the value of grains which has made itself felt in turn in the cost of ethyl alcohol from grain. Much of the molasses distilled is imported from Cuba, Porto Rico and Hawaii. The price of molasses has increased because of great increases in ocean freight rates; in Hawaii, for instance, large quantities are being burned to recover the potash in the ash, the molasses being worth over \$15 per ton for its potassium content alone.

Corn yields about 2.4 gallons of 190 proof alcohol per bushel, and although the price of corn has varied considerably,* both seasonally and annually, and especially in the last few years due to the war, the average cost of the materials used for making grain alcohol (fuel excluded) is about \$0.275 per 190 proof gallon. The manufacturing cost, including coal, interest, repairs, depreciation, taxes, labor, etc., ranges from \$0.10 to \$0.17 per gallon of 190 proof alcohol, depending upon the location and efficiency of the plant. This makes a total of from \$0.37 to 0.44 per gallon, which is greater than the price of denatured alcohol or of ethyl alcohol for denaturing purposes before the war. The reason for this is that the grade of alcohol used for denaturing purposes is not as high as the best that can be produced from grain.

The better grades, which have been redistilled a number of times, and also passed through charcoal, usually command a sufficient premium so as to make up the deficit incurred in the production of alcohol of a denaturing grade. In addition, the above figures apply more particularly to the production of alcohol which is later sold in the form of whiskey and in which a higher quality of grain is necessary than in the production of straight alcohol. It may safely be assumed, however, that the cost of production of alcohol even from condemned grain varies between \$0.25 and \$0.35 per gallon.

One gallon of molasses yields from 0.45 to 0.48 gallon of 190 proof spirit. The price of molasses has averaged from \$0.05 to \$0.075 per gallon, although since the war, and particularly on the west coast, quotations on molasses have gone up as high as \$0.10 per gallon. So that the cost of raw material in a gallon of molasses spirit has averaged from \$0.10 to \$0.15 per gallon, although at the present time it may be nearer \$0.20 per gallon. The cost of production of molasses spirit is slightly less than that of grain spirit, but in either case we have a comparatively high cost of raw material.

One ton of dry coniferous sawdust or other form of waste (or its equivalent on an air-dry or green basis) will yield from 15 to 25 gallons of 190 proof spirit. This material in the vicinity of a sawmill or other large wood working plants is, in some cases, an item of loss, since most of the mills produce waste in excess of their own power requirement. In other cases it is not worth more than \$0.30 to \$0.50 per ton, which, therefore, makes the price of raw material in a gallon of ethyl alcohol from sawdust about \$0.02. This also includes a fuel charge, since the residue after conversion and extraction is available for fuel, whereas in grain and molasses distilleries about seven tons of coal are required per thousand gallons of 190 proof spirit. In grain distilleries, however, the still slops which contain all of the protein and nitrogen that was in the grain are recovered and used for cattle foods, either in feeding pens in connection with the distillery or else are dried and sold as such. This forms a valuable by-product which is not obtained in distilleries operating either on wood or on molasses.

If the manufacturing costs of producing ethyl alcohol from wood can be reduced to a figure approximately the same as the cost of production from grain or molasses, we have a large margin in the cost of raw material in favor of the alcohol from wood waste. Of course, if we compare a yield of 20 gallons to the ton from wood to 80 gallons per ton from corn, we see that the amount of material handled in certain parts of the plant producing alcohol from wood will be four times as great as in a grain distillery of equal capacity, thereby increasing the size of the plant and operating costs. The fermenter and still equipment, however, will not need to be larger than in a grain distillery of equal capacity, so that one of the largest items in the production of alcohol has not been increased.

In recent years the production of ethyl alcohol from sawdust has received a great deal of attention and a great deal of money and effort have been spent in its technical development. A number of plants have been built in this country, but one only of them has, up to the present, been considered a commercial success. Because of the importance of the problem of waste disposal to the lumber industry and because of the adaptability of this process to the disposal of coniferous wood waste in quantity, the Forest Service has investigated both the process and, as far as possi-

*The price of corn graded as No. 2 Common on the Chicago market during the month of May in 1914, 1915 and 1916, ranged from \$0.67 to \$0.79 per bushel.

ble, the plants that have been built in an effort to determine the causes for failure and to aid in its development to a commercial success.

Outline of Processes

The processes used for the production of ethyl alcohol from wood may be grouped into two general classes—first, the hydrolysis or conversion of the wood into fermentable sugars by the use of dilute mineral acid as a catalyst; and second, solution processes in which the wood is dissolved from concentrated acid with a subsequent hydrolysis or conversion of the diluted solution.

Processes of the second class involving the use of concentrated sulphuric acid in which the wood is actually dissolved have not received commercial attention because the amounts of acid used have been so large compared to the processes in which the acid is used merely as a catalytic agent that the large initial and recovery cost for acid have prevented commercial development.

The first process of producing ethyl alcohol from wood consists in general of digesting the sawdust, or hogged and shredded waste, with dilute sulphuric acid at a steam pressure of 60 pounds or more for a short time. This is done in rotary digesters which will thoroughly mix the acid and wood. These digesters are of steel boiler plate with an acid proof lining. A part of the wood is converted into a mixture of sugars, some of which are fermentable. The digested material is next transferred to a diffusion battery similar to that used in the extraction of sugar from sugar beets or dyes from dyewood, and here the sugar and other water-soluble material is extracted with hot water from the digested sawdust. The acidity of the extract is then neutralized with lime or limestone, and the sludge formed by the calcium sulphate and some of the dust carried in the extract is allowed to settle out, which requires ordinarily from 15 to 20 hours. The clear solutions are then drained off and cooled to the proper temperature for fermentation. The fermentation, distillation and rectification of the alcohol are accomplished in the usual manner very similar to the production of alcohol from molasses.

History

The first recorded attempts to produce sugar and alcohol from vegetable fiber were those of Braconnot in 1819. From that time on at numerous intervals other work was published and a number of experimental plants were built, although all of them resulted in failure. This was because the scientific basis for the process had not been worked out. In 1898 Simonsen published the results of his research on the subject, in which he investigated both sulphite cellulose and sawdust in a systematic way. As the hydrolyzing agent he used sulphuric acid and from his results concluded that the best conditions for the inversion of sawdust were as follows:

Time of cooking.....	$\frac{3}{4}$ hour
Acidity	0.5 per cent sulphuric acid
Proportion of wood to dilute acid.....	1 to 4
Cooking pressure	9 atmospheres

The above conditions gave him a yield of alcohol equal to about 6 per cent of the dry weight of wood used. Simonsen, however, made but few fermentation experiments, and therein his work was scientifically weak. A small plant was built in Christiania, but did not work out successfully, chiefly for the reason that such a large volume of dilute acid was used which required an excessive amount of steam to heat the charge and which later gave them liquors which were too dilute to distill economically. A number

of other workers checked Simonsen's work from the scientific standpoint and showed that in general the yields he claimed could be obtained.

Some time later A. C. Classen developed a process in which sulphur dioxide was used as the hydrolyzing agent. Classen took out a number of patents covering the various phases of his process in which both gaseous sulphur dioxide and also the gas dissolved in water to form sulphurous acid were used. This process is of particular interest since it was the beginning of the American development of the production of ethyl alcohol from wood, when in 1903 the patent rights for America were acquired by a Chicago company. This company erected an experimental plant at Highland Park, Chicago, and after demonstrating the process to their satisfaction erected a plant at Hattiesburg, Mississippi, at a cost of about \$250,000 to operate on longleaf pine sawmill waste.

This plant was a failure because of a number of mechanical and technical reasons, the chief of which are as follows: First, the length of time necessary to hydrolyze the wood, this requiring from four to six hours; second, the quantity of acid needed; third, the prolonged action of so much acid and water in the rotating digester reduced the wood to a very fine powder and formed much sulphuric acid, which acted on the sugar and other substances present to form gums and caramels and so made the complete extraction of the sugars from the residue very tedious and expensive; fourth, the digester was lead lined and the buckling and breaking of the lining necessitated repairs after every two or three cooks, which proved a great source of delay and expense.

Ewen and Tomlinson, who were associated with the Classen process, began experimenting along new lines in order to overcome the difficulties which were brought out at Hattiesburg. Instead of using an aqueous solution of sulphur dioxide, the gas was passed into the digester along with steam, which furnished, therefore, both the heat and moisture required.

Somewhat later, however, Ewen and Tomlinson gave up the use of sulphur dioxide and were granted a patent covering the use of sulphuric acid as the catalytic agent. A study of this patent and the process patented about 15 years previously by Simonsen will disclose a remarkable identity as to ideas.

Ewen and Tomlinson, who were then the engineers and technical advisers of an alcohol company, erected a plant at Georgetown, South Carolina, for the demonstration of their process. This plant was later acquired by a powder company, which has operated it intermittently for the last three or four years. The sawmill in connection with the alcohol plant burned down in 1913 and was replaced by a large new mill, which was put into operation about a year later. During this interval the powder company devoted a considerable amount of time and money to research on this problem.

Several years ago western capital erected a plant at Port Haddlock, Washington, on Puget Sound, for the production of ethyl alcohol and cattle food from sawdust obtained from mills at Seattle, Tacoma, Everett, Anacortes and Port Blakely. The plant was equipped with six digesters of the same size and type as those that were developed in France by the Compagnie Industrielle des Alcool de l'Ardeche. These digesters consisted of a steel cylinder $2\frac{1}{2}$ meters in internal diameter by 21-3 meters in length, through which were spaced 22 tubes 160 millimeters in diameter.

Outside of each end of the tube heads are flanged boiler steel jackets, one to receive the live steam from the boiler and the other to take off the condensed steam, the heating being indirect, the idea being to save steam by means of the indirect heating. Sawdust and enough water were added through a man-hole into the space between the tubes to raise the moisture content to about 45 per cent. Anhydrous sulphur dioxide was then added and the mixture was cooked at 75 to 100 pounds pressure.

The cost of conversion was excessive because of the very rapid corrosion of the digesters, the long time necessary to heat indirectly and because the sulphurous acid gas leaked from the digester into the steam space, thereby preventing the use of the low pressure steam. In addition, the extraction equipment was inefficient and out of date. The buildings of the plant were excellent and expensive and much of the equipment was imported from France at a large cost.

The extracted sawdust (which had only from 50 to 60 per cent of the sugar formed extracted from it) was mixed with Hawaiian molasses and was put on the market as a cattle food. It was necessary to dry the extracted material down to about 12 per cent moisture in order to prevent decay and this gave great difficulty due to explosions of dust in the dryers. In addition, the plant was located about 80 miles from a railroad, which greatly increased transportation charges, and these facts, coupled with the very poor design and equipment (especially digester and extraction equipment), were no doubt the prime reasons which caused the failure at this plant.

After disposing of the Georgetown plant to the powder company the alcohol company referred to above underwent a reorganization. A large amount of foreign capital was introduced and a large plant designed to produce 5000 gallons of 190 proof alcohol per day was erected at Fullerton, Louisiana. This plant, to our knowledge, has never operated at capacity or even continuously for any length of time. The plant appears to have cost much more than it should. Even at present it is questionable as to whether or not a number of the units in it are of the size and type to secure maximum efficiency. Because of the fact that the plant was built largely with foreign capital the war has interfered with changes that are necessary and advisable before resuming operation, and the plant has been idle for a very considerable period of its existence.

This short outline is merely a review of the four plants that have been built in this country, only one of which has achieved any measure of commercial success, and does not take into account the very large amount of scientific work that has been done in the last decade and which will be covered fully in a later bulletin to be issued by the Department of Agriculture. The powder company, through its development department, and especially by the work of its superintendent and chemist at Georgetown, has really attempted to investigate the problem in a scientific way. Some of the other plants, especially the one in the West, were built by men without full knowledge of the requirements of an operation of this type, and apparently no technical supervision was obtained to assist and direct the work.

As long as the development of this process, which requires the highest type of engineering and chemical skill, is left in the hands of concerns interested chiefly in the disposal of stock the production of ethyl alcohol from wood will be costly to those who invest in it. In view of these facts the following

outline of plant equipment and operation with cost estimates has been prepared so as to present to the lumberman the actual requirements of an industry of this type.

Plant Requirements

The essential parts of a plant necessary to produce ethyl alcohol from wood considered in the order of their use are the following:

1. Adequate sawdust storage.
2. Disintegrating equipment {

Hogs.
Screens.
Shredders.
3. Sawdust storage above digesters.
Acid storage.
4. Digesters.
5. Diffusion battery.
6. Neutralizing and settling tanks.
7. Coolers.
8. Fermenters and yeast equipment.*
9. Beer still.*
10. Rectifying still.*
11. Bonded warehouse.*
12. Boilers and engines.
13. Laboratory and office.

*These items must be under U. S. Int. Rev. Dept. approval and supervision.

SAWDUST STORAGE

Adequate sawdust storage will vary with the location and continuity of operation, the sawmill, and the character of the logging operation. The operation of the alcohol plant and distillery must be continuous. The storage must be sufficient to permit compliance with the necessary regulations of the Internal Revenue Department regarding the operation of distilleries. The latter are surveyed as to their output and must produce daily the amount required in this survey or else are penalized with the tax on such a quantity of alcohol as is necessary to make up the survey.

In general, therefore, the alcohol plant should have at least a 15-days' supply of wood on hand and, where logging operations are such as to require frequent shut-downs, the alcohol plant should have sufficient material in storage to last twice as long as the usual shut-downs. The waste can be stored and handled easiest in the condition ready for use, that is, hogged and shredded. Protection from the rain is sufficient and any type of open, walled, but covered building would answer the purpose.

Belt conveyers can be used to handle the material and a long open covered shed, with an inclined bottom sloping into a trough, similar to those used for the storage of sugar beets would answer the purpose.

DISINTEGRATING EQUIPMENT

This would consist of hogs or chippers and shredders and screens. A chip $\frac{1}{2}$ in. long with the grain will be penetrated thoroughly with acid, but the ease with which the sugar can be leached out is a problem that would require attention. However, since the residual digested sawdust or waste left after extraction is ample for power production, and all engine exhaust steam can be used for heating and distillation purposes, the extra power required to chip down a $\frac{3}{16}$ or $\frac{1}{4}$ -in. chip would not be prohibitive and the greater efficiency of extraction would probably make it very desirable. After screening and reshredding the screenings the fine stuff would go by belt to the loading bins over the digester.

SAWDUST AND ACID STORAGE

The loading bins should be of sufficient size to act as an intermediate storage for the material as it comes

from the screen on its way to the digester. They should hold four or five digesters full each and should be placed over the digester and tapered down so that the material can flow directly into the digester similar to those in use in chemical pulp plants.

The acid would come to the plant in concentrated form so as to permit tank-car shipment and storage in steel tanks. The concentrated acid would be pumped into a lead-lined tank above the digester and diluted so that the dilute acid could flow into the digester along with the sawdust. If rotating digesters are used no special mixing apparatus will be necessary, at least we have never found evidence of appreciable quantities of uncooked material when handled in this way.

THE DIGESTERS

The digesters should be rotating and may be spherical or short and cylindrical with dished ends. If the latter type is used the diameter should be double the length of the cylindrical section so that it may be filled as completely as possible. A number of satisfactory acid-proof linings are obtainable at present. During cooking the mass shrinks in volume and settles so that the final volume is only about two-thirds the original volume and leaves ample room for thorough mixing during cooking.

The sizes of the digesters will be governed by the daily capacity of the plant, the heating period and the time of the complete cooking cycle per digester. If the heating period is 15 minutes out of a total of 1 hour for each cook, four digesters, or multiples of four, should be used, whereas if the heating period is 20 minutes out of a total of 1 hour only three or multiples of three should be used. In this way the steam load on the boilers will be as uniform as possible and the boiler capacity will be dictated largely by this load, since the rest of the load for power and distillation purposes will be generally constant. In addition, the hogging, shredding and digester capacity of the plant should be such that it will give sufficient digested sawdust in 18 or 20 hours to run the rest of the plant 24 hours, thereby giving time for repairs and breakdowns.

The cooked sawdust can be discharged merely by rotating the digester and falls into a bin which receives the cooked material from all the digesters and from which it goes by a mechanical conveyor to the different cells of the diffusion battery.

DIFFUSION BATTERY

Closed cells similar to those used for the extraction of sugar beets or dyewood chips can be used. These should be lined so as to be acid resistant like the digesters and the top and bottom should be arranged so that charging and discharging can be readily accomplished. Cells of this type can be obtained in which the extracted material will empty itself after a release of the bottom of the cell. The temperature of the extracting water should be from 75 to 90 deg. C., since this will give not only a greater solubility than colder water but will also sterilize it and will keep the juice sterile while it is settling after neutralization.

The size of the cells and the number of cells in the battery and the amount of water per cell will be governed by the size of the plant and the size of the material that is cooked, since sawdust, for instance, will extract more readily than larger material. As our leaching experiments have shown, seven or eight extractions seem to be necessary; this would require eight or nine cells in the battery, since one is being discharged and filled all the time. Since the sugars are readily soluble, only a short extraction period is necessary, that is, from 5 to 10 minutes on each cell, or a total extraction period of from 50 to 75 minutes. This time, how-

ever, will be governed in part by the length of time that it takes the water to drain through each cell, which in turn depends on the size of the cell. The cells should not be too large, or the extracting water will not pass through the material easily, and the amount of water used should be such that the resulting extract is of the proper concentration for fermentation, which is from 11 to 12 deg. Brix. The Brix will go up another degree on neutralization.

Just as in the case of laboratory extractions, or washing of precipitates, a large number of extractions or washings with small amounts of liquid will give a better extraction or more thorough washing, and a more concentrated extract, than fewer extractions with larger amounts of extracting water for each extraction.

NEUTRALIZATION AND SETTLING

After extraction the acid extract is nearly neutralized with solid or milk lime or a high grade limestone (a magnesia stone is undesirable) and is then allowed to stand so as to settle out the sludge of calcium sulphate. This usually requires from fifteen to eighteen hours so that adequate tank capacity is required here.

COOLERS

The clear juice is then drawn off and passed through coolers to reduce its temperature to about 27 deg. C., from which it goes into the fermenting tanks. The coolers should be of copper and their size will depend upon the temperature of the water supply available.

FERMENTATION, DISTILLATION, ETC.

A 96-hour fermentation period is permitted, so that a four-day fermenter capacity is required. The size of the individual fermenter will be dictated largely by local conditions, such as mean temperature, and the other equipment is the standard distillery equipment in use at present in grain or molasses distilleries.

POWER REQUIREMENTS

The steam load of the plant will be distributed about as follows:

	Per Cent
Pumps	20
Boiler	
Fire	
General water supply	
Beer	
Alcohol	
Digesters	30
Hogs and shredders	20
General power from driving conveyors, digesters, etc.	15
Distillation and rectification	15*

*Including all exhaust steam not used for heating boiler feed and extraction water. If large quantities of exhaust are not available, distillation and rectification may require as high as 40 per cent of the total load.

A large supply of pure cool water is necessary. It should be pure for boiler and extraction use and should be cool for use in cooling and condensing. The disposal of the beer still slops requires attention because of the large amount of pentose carbohydrate, and also of dead yeast which is highly nitrogenous and which would lead to rapid putrefaction.

COSTS

The production of alcohol by this process has up to the present time with possibly one exception, as outlined before, not been a commercial success. With new developments at the Forest Products Laboratory, allowing the necessary manufacturing losses involved in extraction, in the sludge of the settled juice, and in distillation and rectification losses, which combined should not be 20 per cent of the total yields, a yield of over 20 gal. per dry ton has been obtained.

Assuming this yield and a location where the supply of waste is uniform and constant for a period of twenty years and where plenty of good water may be had, and

where there is a fairly close supply of sulphuric acid and lime, the cost of alcohol from wood in a properly designed and constructed plant of 2500 or 3000 gal. per day capacity, is estimated per gallon of 190 proof as stated in Table I.

TABLE I	
Yeast nutrients	\$0.015 to \$0.020*
Repairs and materials (exclusive fuel and wood) ..	0.030 to 0.040
Labor	0.015 to 0.030
Wood and fuel	0.020 to 0.020
Interest at 7 per cent.	0.019 to 0.020
Depreciation at 10 per cent.	0.023 to 0.035
Overhead, taxes, etc.	0.015 to 0.030
Total	\$0.137 to \$0.195

*This item may go as high as \$0.035 in some sections since the war; also rapidly advancing prices of iron, steel and copper, particularly the latter, will require some increase in the above estimate, which was figured for market conditions existing over a year ago.

In Table I wood has been valued at \$0.40 per cord of 1800 lb. of dry wood per cord. This should consist of sawdust and hogged refuse but should not contain over 10 per cent of bark, since the yield of sugars and alcohol from bark is very low. A large quantity of bark would mean running a large volume of inert material through the alcohol plant at considerable expense without return and in the case of most barks would add large quantities of undesirable tannin to the solutions to be fermented.

Before the war alcohol for denaturing purposes could be obtained in quantity for \$0.30 per 188 to 190 proof gal.; at present (June, 1916) the market value runs as high as \$0.67 per gallon for small lots with, no doubt, appreciable shading for contracts in quantity. The price, however, has gone up from 33 1/3 to 50 per cent and as long as the war continues no appreciable decrease in price seems probable because of the demands for grain and molasses for other purposes and because of the enormous amounts of alcohol being used. Before the war from 10,000,000 to 11,000,000 gal. of denatured alcohol were being produced annually. This production has now increased to over 30,000,000 gal.

Under normal operating conditions most mills, particularly the large ones, produce waste in excess of their own power requirements and in large mills equipped with efficient power plants this excess will be from 50 to 65 per cent of the total produced. The disposal of this waste by means of a burner is, therefore, almost invariably necessary. The cost of burning this waste varies widely with the size and efficiency of the mill, but from figures gathered by this laboratory this expense ranges from \$0.30 to \$0.66 per cord, or from \$0.11 to \$0.22 per 1000 ft. on all of the lumber cut, and means that the present cost of waste disposal amounts to about \$6,000,000 annually, in addition to the value of the wood so burned.

All waste, therefore, that could be disposed of for the production of alcohol would not only net the sawmill about \$0.40 per cord but would also relieve them of the charge of burning which, as given above, ranges from \$0.30 to \$0.66 per cord and which, therefore, practically doubles the above realization to the sawmill.

In other words, an operation of this kind in conjunction with the sawmill would add from \$0.22 to \$0.45 per thousand to the value of all lumber cut. This applies particularly to mills cutting coniferous species to which the above alcohol yield and waste disposal figures apply.

From work going on at present, it seems that the yields from some of the hardwoods will not be as great as those obtained from the coniferous species.

In conclusion, the successful production of ethyl alcohol from sawdust seems to depend upon the proper design, equipment, and management of the plant, rather than its chemical or fermentological features. Large volumes of low grade materials must be handled

quickly and efficiently under unusual technical conditions. The perfection of the necessary acid-resisting pieces of apparatus, along with the experience of the plants that have been built, together with the utilization of material whose mere removal at present is an expense justifies a serious consideration of the future of this industry.

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The Flotation of Minerals*

BY ROBERT J. ANDERSON

During the past 5 years no subject has aroused more interest or received more attention among mill operators than flotation. One reason for this is, undoubtedly, the remarkable success of the process in Australia where that country has risen to the position of furnishing one-fifth of the world's supply of zinc. The plant of the Butte & Superior Copper Co., designed by James M. Hyde in 1912, was the first important large flotation plant in this country; other installations have been made since then with considerable frequency, particularly so in the last 2 years.

Without going into complete detail, it may be safely said that although flotation is a highly successful commercial process, it is more or less on an empirical basis. Upon scanning the literature, it is found that the flotation investigations have, in the main, dealt with a solution of the problems which accrue to practice; until recently no attempt was made to remove the difficulties in the way of the formulation of a consistent and harmonious theory. Of late this phase of the work has been receiving considerable attention, particularly by the United States Bureau of Mines at its Salt Lake City station, by the Mellon Institute at Pittsburgh, by the General Engineering Co. at Salt Lake City, by many of the mining schools, and private individuals almost *ad infinitum*. There is, at present, an enormous amount of laboratory work being carried on in flotation research, and probably the time is not far away when a generally acceptable explanation of flotation phenomena can be set forth. However, at this time, it seems as though the current technology is befogged with a superabundance of contradictory evidence; this confusion can only be dispelled as time proceeds and the knowledge of the subject becomes more complete.

Many phenomena are supposed to contribute to the flotation of minerals, whether in whole or in part is a mooted question. I shall only sketch roughly the present tendency of ideas and make no reference to the first early and crude notions which have little value other than historical interest. Many questions have arisen in connection with flotation concerning such matters as surface and interfacial tensions, adsorption, absorption or occlusion, colloids, emulsions, electrolytic and electro-static phenomena, etc. These phenomena are to be discussed in later paragraphs in order to ascertain what bearing they may have, if any, on froth flotation. No final solution of this very large problem is attempted in this paper, for in any discussion of flotation theory, at this time, one is confronted by so many obstacles that at best only a rather fragmentary presentation can be made. An attempt has been made in this writing to correlate the operative and fundamental principles and compare in a measure some of the theories so far advanced.

Discussion of Certain Factors

SURFACE AND INTERFACIAL TENSION

Surface tension has been rather well defined in arti-

*A paper to be presented at the Arizona meeting of the American Institute of Mining Engineers, September, 1916.

cles appearing in the *Journal of the American Chemical Society* during the years from 1908 to 1913. The theory of surface tension has been treated in particular by Laplace, Gaus, and more recently by Van der Waals, and by Willows and Hatschek.¹ As defined by Jones,² "potential energy, present at the surface of liquids, produces a tension which is known as surface tension." The phenomena which are invariably indicative of surface tension are commonly observed: Drops of a liquid not exposed to an external force, *i.e.*, either suspended in another liquid of the same specific gravity or freely falling, assume a spherical shape, the sphere being that form of body with the smallest surface per given volume; further, if water be placed in an open vessel its surface film will be a measurable quantity, and its thickness will vary with a number of factors of which temperature is one. Its thickness is observed as ranging from 4×10^{-8} cm. to 4×10^{-7} cm., and its density, when referred to the main bulk of the water below, will approximate 2.14. Surface tension is not affected by the surface area. It is numerical in value and expressed in dynes per centimeter. It is a variable factor dependent on temperatures, increasing numerically with falling temperature, *e.g.*, water at 18 deg. C. has a surface tension of 73 dynes per centimeter, and at 0 deg. C. 75 dynes per centimeter. At the critical temperature of a liquid its surface tension becomes nil.

All liquids have a definite cohesion or tensile strength, which is ascribed to the well-known mutual attraction of their molecules. This then is comparable to a pressure existing within a liquid, which has been termed the "intrinsic" pressure. Naturally the value of the surface tension of solids is numerically a high one. The surface tension of a pure liquid against its vapor can be and is markedly affected by the addition of soluble contaminants. Some salts will raise the surface tension of water while others will lower it; the fact that the salts of weak acids will lower the surface tension of water is explained by the fact that free acid is liberated by hydrolysis. It is further known that all acids will lower the surface tension of water. The surface tension of water is decreased by the addition of oil, or better, oil will reduce the interfacial tension between the water-air phases. A phenomenon for which no explanation has been given is the one which shows that the addition of contaminants may either raise or lower the surface tension of water, but such addition, while it may decrease that tension greatly, can increase it only slightly. Any lowering of surface tension is more marked in a liquid which has a high surface tension, *e.g.*, water, than in liquids of low surface tension.

There can be, of course, no surface tension without adsorption, which produces, in the case of positive adsorption, an increased concentration resulting from a lowering of the surface tension by the contaminating and dissolved substance whatever it may be. The equation of Gibbs— $u = -c/Rt \cdot d\sigma/dc$ —gives the relationship between surface tension and the distribution of the solute between the bulk of the liquid and the film interface. Here the notation is:

- u = excess of substance in the surface layer,
- c = concentration in the main body of the liquid,
- R = the gas constant,
- t = absolute temperature,
- σ = surface tension.

This shows that when the surface tension is reduced by the addition of a contaminant, the quantity $d\sigma/dc$ is

negative and u is positive (from algebraic consideration). The surface film then contains more of the contaminant than the main body of the solution. If the surface film contains less of the contaminant than the main body of the solution it is a case of negative adsorption.

As given in the foregoing, the surface of a liquid against its vapor is in tension—surface tension; the surface of a liquid against another liquid, or a gas or solid, is also in a state of tension: this is termed interfacial tension. In the consideration of the bearing which surface and interfacial tensions have on froth flotation, this condition of affairs obtains in the flotation machine: Pulp consisting of ore of approximately 80-mesh, water in ratio of 3:1 of ore, and oil in disappearingly small amount, is being violently agitated. For the sake of a specific case, the air is being forced mechanically into the swirling pulp by beaters or stirrers. These phases then are present in flotation by the oil-froth process, *viz.*, solid-liquid (ore-water), solid-liquid (ore-oil), solid-gas (ore-air), liquid-liquid (water-oil), liquid-gas (water-air), and liquid-gas (oil-air). Thus six tensions are present, but if the oil is soluble in the water the tension number becomes three. It is known that pure water can not be made to maintain a persistent froth because its surface tension is too high. Acid, if present, will lower the surface tension of water, as will oil if it is soluble to any extent. Very many interesting and important, as well as speculative, consequences follow from a consideration of interfacial and surface tensions, and, in a later paragraph, we shall have occasion to return to the consideration of these complicated phenomena.

Certain metallic sulphides, *e.g.*, galena, have the power of floating on undisturbed water; they are not wetted and the curve of contact is convex. Some gangue minerals, *e.g.*, quartz, possess an adhesive force of attraction for water which exceeds the intrinsic pressure of the water; they are therefore wetted and sink to the bottom, being drawn through the surface film. Such properties of the minerals are affected by the presence of oil, acid, and other reagents. Oil has a greater adhesive attraction for sulphide minerals than for gangue minerals; and the addition of acid and oil (if it is soluble) acts as a contaminant which will lower the surface tension of the water and aid in the production of a persistent froth. Let us now look into the question of adsorption and see what part it plays in flotation, since it is so requisite to the production of a variable surface tension.

ADSORPTION.

Generally speaking, adsorption deals with the unequal distribution of substances at the interface between dissimilar phases such as, solid-solid, solid-liquid, solid-gas, liquid-liquid, liquid-gas, and gas-gas. It is purely a physical effect. Commonly, adsorption³ is construed to be the result of the condensation of a disperse phase upon the interfacial boundary solid-liquid. Returning for a moment to the Gibbs equation mentioned above, adsorption may occur if the interfacial tension solid-liquid is reduced—this being positive adsorption. If, however, such an interfacial tension is raised in value it is a case of negative adsorption as the solute or disperse phase will be rejected from the surface. Any condensation, strictly stated, of a solute or disperse phase in the interfacial boundary separating liquid-liquid or liquid-vapor is held to be a special case of adsorption. However, in the general sense, the phenomenon is looked upon as being the

¹Willows and Hatschek: Surface Tension and Surface Energy, 1915.

²Jones: Elements of Physical Chemistry, 1907.

³Briggs: Journal of Physical Chemistry, Vol. XIX, No. 3, p. 210 (March, 1915).

result of condensation of a disperse phase in the interface of two immiscible phases. Adsorption is shown very strikingly by colloid gels—the product obtained by the coagulation of sols—and certain cases of selective adsorption are very remarkable. Adsorption will naturally vary with the surface exposed. In Miss Benson's experiments with amyl alcohol in aqueous solution, amyl alcohol reduced the surface tension of the water, and it was found by producing a voluminous froth that the alcoholic concentration in the froth exceeded that in the bulk of the aqueous solution by about 5 per cent. A froth has a very large surface, and it would be expected that the adsorption would be greater. Such experiments prove the value, qualitatively, of the Gibbs rule.

Recent work shows that all solids do condense certain amounts of gases on their surfaces and retain them there with very great tenacity. Liquids in like manner adsorb gases. Further, liquids and solids exhibit marked selective adsorption of gases. Although this selective adsorption obtains, no evidential proof has been submitted which says that the amount of gas adsorbed by one substance is largely different than the amount adsorbed by another substance. An electric charge on an adsorbed substance probably would considerably influence the amount adsorbed. The adsorption of air plays an important rôle in flotation, for as Breuer points out, the adsorbed air film is enormously responsible in preventing the coalescence of solid particles.

A comprehensive study of the adhesion of small particles of solid to the dineric interface (surface separating two liquid phases) has been made by Hofmann,⁴ based on the theory of Des Coudres.⁵ From the standpoint of flotation this may be given as follows: If a solid particle, *e.g.*, quartz, is wetted much more strongly by water than by another liquid, *e.g.*, oil, the water will displace the oil, and a film of water will form about the quartz particle according to the relative forces of adhesion. Then the quartz particles will remain in the water phase if the water has a specific gravity greater than the oil, regardless of their size; but if now the oil has a greater specific gravity than the water, then the quartz particles will remain in the water phase until the size of the particles is such that the force of gravity will remove them from the water. Conversely, if a solid particle, *e.g.*, galena, is wetted more strongly by oil than by water, the oil will form a surface film about the particle and hence prohibit the particle from being wetted by water, *i.e.*, from entering the water phase. Then the galena will only enter the water phase when the water is more dense than the oil, and, further, when the galena particles are of such a size that the force of gravity overcomes the adhesion of the oil film to the oil.

Returning to purely theoretical considerations, Hofmann draws certain conclusions at this juncture which deal with the supposition that solid particles will then remain in the surface separating two immiscible liquids, if those particles are wet partially by each liquid. I quote Bancroft at length on this matter:⁶ "The solid particles tend to go into the water phase if they adsorb water to the practical exclusion of the other liquid; they tend to go into the other liquid phase if they tend to adsorb the other liquid to the practical exclusion of the water; while the particles tend to go into the dineric interface in case the adsorption of the two liquids is sufficiently intense to increase the miscibility of the two liquids very considerably

ably at the surface existing between solid and liquid."

Any simultaneous adsorption of two immiscible liquids by a solid would probably tend to result in the formation of a homogeneous liquid phase at the surface of the solid.

In regard to the effect of contaminants or other impurities in contact with two immiscible liquids, this condition obtains: If the contaminant is soluble in one liquid but not in the other, and also lowers the interfacial tension of the two, the equation set forth by Gibbs exacts the requirement that the contaminant should obtain in the interface. Examples of this prove the validity of the law.

The terms adsorption and absorption have been used interchangeably in some writings, thus contributing to the already existing confusion of ideas.

ABSORPTION OR OCCLUSION.

There are three ways by which gases can be held with reference to solids: *viz.*, (1) By surface adsorption; (2) in solid solution; and, (3) by occlusion. The term "occlusion" has been applied indiscriminately to any of these above methods by which gases are held by solids. Strictly speaking, by occluded gas is meant gas which is adsorbed and held in finely divided pores or openings which may be of microscopic size.

A recent theory⁷ holds that occlusion plays the operative rôle in the flotation of minerals by all processes. I am unable to reconcile myself to this explanation for a number of reasons. Marked instances of occlusion at normal temperature are known only in certain amorphous substances like charcoal. Many metals, of course, both in the liquid and solid states, have the power of occluding gases, often in marked degree. There may be and undoubtedly are fine pores in the floatable minerals, which may in a sense be considered as an assemblage of capillary tubes; these can and do occlude gas. Yet occlusion is marked only in amorphous substances and in certain metals as just stated. It is definitely known that occluded gases are retained with very great tenacity by the substances occluding them and therefore expelled only with difficulty. It seems anomalous then to hold that the occluded gas can depart from the mineral occluding it with sufficient speed to aid the air bubbles in the liquid in the process of flotation.

I believe rather firmly that occlusion is not a cogent factor in flotation by any process, and that a more consistent theory may be formulated without postulating these conjectures regarding occlusion.

COLLOIDS.

Colloids, in the original definition of the term by Thomas Graham, are not a definite class of substances; rather a large number of different substances may be made to assume the colloidal state if proper precautions are taken. All of which reveals the striking fact that this colloidal condition is a *state* and not a *form* of matter. The ultra-microscope of R. Zsigmondy and H. Siedentopf has increased the knowledge of colloids to a great extent. A rather general statement may be made regarding colloids and that is, that they do not show osmotic pressure in any appreciable amount. Colloidal solutions—sols—are regarded as systems of two phases, in which the dissolved substance is the disperse phase and the solvent the continuous phase.

Since in flotation the ore is often as small in size as certain of the colloids, the flotation pulp, (ore, water, etc.) can be looked upon as a coarse suspension, and the laws of colloids apply here with equal force as in

⁴Zett. Phys. Chem., Vol. LXXXIII, p. 385, 1913.

⁵Arch. Entwicklungsmechanik, Vol. VII, p. 325, 1898.

⁶Bancroft: Journal Physical Chemistry, Vol. XIX, No. 4, p. 287 (April, 1915).

⁷Durell: Mining and Scientific Press, Vol. CXI, No. 12, p. 428 (Sept. 18, 1915), and Durell: METALLURGICAL AND CHEMICAL ENGINEERING, Vol. XIV, No. 5, p. 251 (March 1, 1916).

the realm of colloidal chemistry. So-called suspensions are systems consisting of solid particles of microscopic size distributed through a liquid. As mentioned by Ralston,⁸ Reinders has treated at length the particular case of a solid phase maintained in contact with two liquid phases, *i.e.*, two immiscible liquids. His work is based on the different interfacial tensions existing, and his experiments and those of Hofmann, as mentioned in an earlier paragraph, have considerable bearing on the flotation problem.

EMULSIONS.

Emulsions are fairly coarse dispersions of one liquid in another with which it is immiscible. The simplest and commonest emulsions are the oil-water emulsions, *i.e.*, the pure oil-water emulsions, containing no emulsifying agent such as soap, proteids, etc. In such systems the oil globules can be coagulated by electrolytes, show the Brownian movement strikingly, and can even be retained by some filtering media. Any process of emulsification is dependent on a surface tension lowering, or, to be more precise, on a lowering of the interfacial tension between the two phases. According to Briggs and Schmidt,⁹ the two essential requirements of an emulsifying agent are these: (1) The property of condensing by adsorption in the dineric interface; and (2), the ability to form under these circumstances a strong coherent film. Temperature is a cogent factor in emulsification, for its effect is to reduce the interfacial tension between phases and also to lower the viscosity of the phases. In the production of emulsions, a considerable amount of surface energy is produced because of the relatively large surface area of the disperse phase; an emulsion is the more speedily effected if such surface energy be reduced by the use of a liquid having a low surface tension as the continuous phase. Some emulsions, under certain conditions, display a great increase in viscosity over that of either of the immiscible phases, *e.g.*, the emulsions of the Pickering order—up to 99 per cent of oil in 1 per cent of soap solution—can be cut into cubes. Any emulsion produced with soap solution is at once rendered nil by the addition of acid as the latter will decompose the soap.

If solid particles are suspended in a liquid, they tend to increase the viscosity of that liquid only gradually depending on the amount of solid particles present. Experiments have shown that whenever a substance which is in suspension is wetted by two immiscible liquids simultaneously, it will go into the dineric interface in the manner already referred to, and will therefore tend to produce an emulsion. If, however, the suspended particles can not coalesce due to adsorbed oil film or for other reasons and thus effect the production of a coherent film, the emulsion will not be stable. Very little data are available on the production of emulsions by the oils used in flotation work, or on the matter of interfacial tensions between such oils and water. However, we are no doubt dealing with emulsified or partially emulsified pulp in some of the flotation processes, *e.g.*, the oil-froth process at least.

ELECTROLYTIC AND ELECTROSTATIC PHENOMENA.

Any substance which is placed in contact with water or many other liquids will assume an electric charge, the origin of which is, as yet, not set forth. Most substances when in contact with water become negatively charged, but these charges can be differed at will or reversed by the addition of the proper electrolyte in re-

quisite amount. These electric charges are by no means confined to submicroscopic particles but are found also on the particles of a coarse suspension. Gangue minerals, *e.g.*, quartz, when suspended in water, are negatively charged, and sulphide minerals, *e.g.*, pyrite, are positively charged under like conditions. Oil drops are negatively charged, as are air bubbles under certain conditions which will be given subsequently. These charges are very minute when referred to the mass of the particle. Substantial evidence is at hand which goes to show that floatable minerals have the positive sign of electricity when suspended in water or can be made to assume that sign by the addition of proper electrolytes in sufficient amount. As Callow¹⁰ observes, there is a parallelism between electrostatic characteristics and the flotation properties of ores. Many of the electrostatic principles have either been carried too far or misapplied as recent work shows.

Experiments in the realm of colloid chemistry indicate that the contact films are charged and that such charges markedly affect the dispersion or coherence of the particles in suspension. Naturally, oppositely charged contact films will coalesce while similarly charged contact films will repel each other, if the charges are sufficient in amount to overcome the force of cohesiveness; in the latter, dispersion is the result. The oil and air contact films having negative charges would tend to attract the sulphide particles, but further than this possibility electrostatics probably plays little part in flotation for the reasons given in the following paragraph.

As referred to above, it is pretty generally admitted that only minerals which are good conductors are suitable to flotation. Now then, as the electrical theory contends, electrified bubbles must be supplied to float the conducting minerals which are attracted, leaving behind the minerals which are not. The bubbles in flotation are simply air spaces contained by a mantle of oil or water, and there is, therefore, nothing within to bear the charge. In case it could carry a charge, which would only be possible by the presence of contained ionized gases or water vapor, the charge would be speedily dissipated by contact with the interfacial boundary. Then in order for a bubble to carry a charge it must be protected by a dielectric film. Further, electrostatics plays probably little part in holding the sulphide particles and the gas bubbles together as neither the bubble nor the particle can have a charge of sufficient magnitude when referred to the size. The electrical theory has been strongly championed by at least one writer¹¹ and has been tolerated by some others. A recent article¹² indicates that the principles of electrostatics have been considerably misapplied. It is my belief that electrostatics may be a small contributing factor in flotation in a manner not as yet understood because of a lack of data concerning charges at the interfacial boundary between immiscible phases, *e.g.*, where the colloidal state is introduced in oil-water emulsions. Apparently, as far as any data at hand are concerned, they all serve to condemn any attachment of great importance to the electrical theory.

The Character and Formation of Flotation Froth

Bearing in mind the phenomena discussed above, let us turn to the flotation of minerals by means of the froth process and look into the character and formation of froth. A froth has been defined as a multiplic-

¹⁰J. M. Callow: *Bulletin, A.I.M.E.*, No. 108, p. 3342 (December, 1915).

¹¹Bains: *The Electrical Theory of Flotation, Mining and Scientific Press*, Vol. CXI, No. 22, p. 824 (Nov. 27, 1915).

¹²Bains: *The Electrical Theory of Flotation, II, ibid.*, Vol. CXI, No. 24, p. 883 (Dec. 11, 1915).

¹³Fahrenwald: *The Electrostatics of Flotation, ibid.*, Vol. CXI, No. 11, p. 375 (March 11, 1916).

⁸Ralston: *Mining and Scientific Press*, Vol. CXI, No. 17, p. 624 (Oct. 23, 1915).

⁹Briggs and Schmidt: *Journal of Physical Chemistry*, Vol. XIX, No. 6, p. 479 (June, 1915).

ity of bubbles; this seems to be wanting in some respects but will be requisite and sufficient for this purpose. The froth of flotation is formed by the action of air or gas in water containing impurities or contaminants, for pure water will not maintain a froth.

FROTH AND BUBBLES.

The idea has been abandoned of late, by most people, that a low surface tension is the essential requirement for froth formation. As mentioned by Coghill in a recent writing, the contamination of the liquid with an impurity which will cause a variable surface tension is the real requirement. A bubble of air is spherical in shape and this shape can only be maintained if the external pressure exceeds the internal pressure. Since a bubble does not expand *per se*, large bubbles can only be accounted for by heat, coalescence or electrification. Viscosity is an important factor in froth persistence as it increases the tenacity of the liquid film and thus prevents ready rupture. The rupture or bursting of bubbles is accounted for by these reasons:

1. Concussion upon a surface film which is deficient in the requisite viscosity and variable surface tension.
2. Relief of pressure—here the gas of the bubble in expanding exerts a pressure which exceeds that of the liquid film.
3. Adhesive force of the entrained gas for the atmospheric air.
4. Evaporation of the liquid film.

Flotation bubbles will burst then for any one or a combination of all these reasons.

Solutions in which the continuous phase is a solution of soap, various products from the saponification of albumens, etc., will froth voluminously even in a very diluted condition; frothing never occurs in pure liquids and is a definite proof that the solute or disperse phase lowers the surface tension of the solvent. A froth, which shows adsorption at the interfacial boundary of solution and gas, depends for its persistence on the production of a viscous film at that boundary; these viscous films are the direct result of surface adsorption of the disperse phase, *i.e.*, dissolved contaminants, the amount of which is small—disappearingly so. The work of Hall and of Miss Benson shows that in a foaming liquid the foam is richer in dissolved contaminant than is the bulk of the liquid. Froth formation in the Callow cell is the result of the injection of air into the pulp (already emulsified); the froth continues to obtain as long as there is sufficient air injected into pulp of the proper consistency. The froth in the Callow cell is governed in nature by the kind of oil used and by the amount of air. A pneumatic froth is unstable or ephemeral, *i.e.*, it dies rapidly when removed from the influence of the injected air. The mechanical froth, on the other hand, is thick and persistent, and must be broken up in dewatering the concentrates.

OILS

Oils have a well-marked selective action for metallic sulphides, tellurides and some other minerals. The fact that both the oil and the air or other gas have a selective adhesion for sulphides prevents them from being wetted by water. Conversely, the quartz and other minerals exhibit just the opposite characteristics. The gangue minerals, generally, do not exhibit adhesion for either gas or oil, and hence they are readily wetted by water. Gases have a well-defined adhesiveness for oils; hence the air or gas adheres strongly to the oil film. The stability of a froth depends, in the main, on the kind of oil used, *e.g.*, pine oil makes a weak brittle froth, and creosote makes a stable elastic froth. The

work of Devaux¹³ on oil films explains how so small an amount of oil as is used in the various flotation processes can be so efficacious. From a consideration of the immiscible oil-water interface, if any oil will film the internal surface of a gas bubble the sulphide mineral particles would be contained in the oil-water interface no matter what the nature of the gas contained by the water film. The sulphide, if it enters the oil phase, would then present an oiled surface to the water phase. There are three conditions then: (1) The mineral enters the oil phase completely; or (2) the mineral enters the water phase completely; or (3) the mineral enters the oil-water interface.

Some experiments made to determine the nature of the frothing power, selective and collective action of different oils show some interesting results. I made some tests on a zinciferous slime from the Joplin area with different oils and the results obtained indicate that a definite mixture of oils will effect better recoveries than any one oil alone. The best combination consisted of pine oil as a frother, plus wood creosote as a frother and selector, plus refined tar oil as a froth stiffener. The complete results of these experiments will be given in a later paper.

In general, pine oil makes a brittle froth which immediately dies; creosotes make a more elastic froth, the bubbles of which may expand to 3 in. in diameter or more before rupture. Coal-tar products are rather poor frothing agents and if used must be aided by either creosote or pine oil to produce a good froth. Oils of a lubricating nature seem to be of little value as flotation oils, while such light oils as gasoline and naphtha are of value only for thinning the heavy coal and wood tars.

AIR AND GAS

At this time there are three ways by which a gas may be forced into a solution mechanically, *viz.*:

1. By beating it into the solution by means of beaters or paddles—as in the Minerals Separation and similarly mechanically agitated machines.

2. By pneumatic means—as in the Callow cell where the air is divided by the porous blanket bottom into minute sprays.

3. By so-called liquid jets—as in a process recently patented in which the air is introduced as a surface film surrounding a liquid jet by surface tension.

Conversely, there are three methods by which dissolved gas may be expelled from a liquid, *viz.*:

1. When the liquid is supersaturated, the excess gas is expelled.

2. By heating the liquid, when some of the gas is expelled due to an increase in its volume.

3. By pressure reduction, as in the Elmore vacuum process, where, according to the law of Henry, "the amount of gas dissolved by a liquid is proportional to the pressure to which the gas is subjected."

An air or gas bubble on being introduced into a liquid is at once surrounded by a film of the liquid. Such a bubble will rise to the surface (carrying the metallic sulphides by reason of the forces already mentioned) on account of gravitation, by which is understood that the adherence of the air to the liquid is less than the force of gravity.

Résumé

From a consideration of the foregoing, it is believed that the theory based on the different interfacial tensions involved is the dominating one as well as the more consistent at this time. Probably flotation is due to a combination of phenomena which are rather high

¹³Devault: Oil Films on Water and on Mercury, Smithsonian Report of 1913, p. 261.

¹⁴Jones: Elements of Physical Chemistry, p. 177, 1907.

in the scale of complexity. The theory based solely on occlusion goes "by the board" as it has been shown that the contributing effect of this phenomenon has been interpreted rather laxly.¹² The phenomenon of electrostatics may be a small contributing factor but recent work indicates that the principles have been misapplied. An explanation more in consonance with fact can be given in terms of the interfacial tensions involved, without postulating either occlusion or electrostatics, as mentioned above.

The main and essential requirements for froth flotation are: (1) The production of a persistent froth by any means; (2) the attachment of the bubbles of air to the sulphides or other material to be floated; and (3) the maintaining of a selective action of the froth bubbles for the sulphides or other material to be floated.

Why this is accomplished is outlined in the above, particularly under the subhead, "Adsorption." Probably, before any generally satisfactory estimate of the many complex factors, which are supposed to be involved, can be secured, a more thorough investigation of all of them will have to be made than has thus far been attempted. However, in this line of inquiry there has been a steady progression of thought and a remarkable increase in knowledge in the past few years; and the art of flotation will continue to improve and develop as the more complete knowledge of the different factors involved increases and allows the exercise of a better control of them.

Missouri School of Mines,
Rolla, Mo.

Testing the Durability of Pipe Under Corrosion*

BY F. N. SPELLER

All will agree that a service test, or at least a test under service conditions, is the only reliable method for determining the relative durability of iron and steel products. However, to be of any value it must be possible to carry such a test to conclusion in a reasonable time. The so-called "acid test" quickly attracted attention, but as this proved to be misleading the effect has been to discount any attempt to accelerate corrosion. Nevertheless, there are certain conditions commonly found in service where pipe is subject to aerated water at a temperature of 140 to 180° F. under pressure, where corrosion is very severe. The method of testing here referred to works under such conditions, which are more or less common to all water and steam-pipe service.

The main factors controlling corrosion in pipe are:

1. The amount of free oxygen in solution in the water.
2. The volume of flow, which is an important factor, mainly on account of the greater amount of oxygen available; and
3. Temperature. Corrosion increases with the temperature, reaching a maximum somewhere between 160 and 180° F.

These conditions are reproduced in the apparatus shown in Fig. 1. This consists of a tank reservoir open at the top, which may be filled with a supply of any kind of water selected for the test. This water is main-

tained at any desired temperature by means of a small gas heater *B* fitted with a thermostat, or a steam coil may be inserted if more convenient. An ejector is provided at *C* and operated by air under three or four pounds pressure. The air should first be passed through a mass of excelsior or similar material to re-

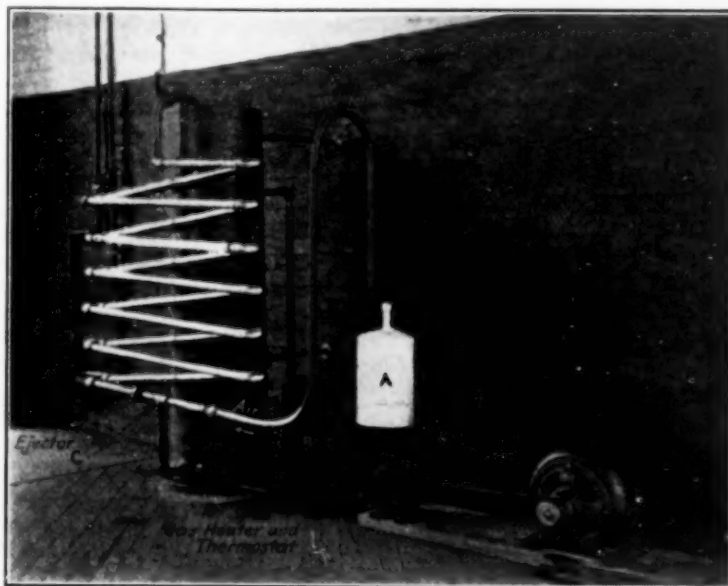


FIG. 1—APPARATUS FOR CORROSION TESTING, USING AERATED HOT WATER

move oil. The heated water is thus aerated, forced up through the coil of pipe and discharged continuously into the top of the tank. The coil consists of alternate lengths of the materials under test. A glass tube may be inserted in the coil if it is desired to observe the flow. By keeping up a continuous flow in this way at a temperature of 160 to 180° F. the relative tendency of pipe to corrode may be determined in three to four months. The amount of corrosion found in that time with this apparatus will be found equal to about two years under the same conditions in actual service.

The acceleration of corrosion in this apparatus is principally due to the continuous flow and the greater amount of oxygen and carbonic acid which is thereby brought into contact with the interior surface of the pipe. The details of this machine may be altered according to local conditions. If the water is not fresh and almost pure, the supply should be renewed from time to time.

The amount of corrosion in both wrought-iron and steel hot-water supply pipe, as measured by the depth of pitting, will frequently amount to about 0.1 in. in two years. We have found with this apparatus nearly this amount of corrosion in pipe of this kind in three months, with the water circulating at the rate of one to two gallons per minute. The relative depth of pitting is apparently the same in each case.

The writer has used this scheme for two years in research work on the improvement of pipe and pipe coatings, with much saving of time compared with similar tests on pipe in actual use.

Increased Production of Bauxite.—The production of bauxite in 1915 showed an increase of 34 per cent over the 1914 output, due to the great demand for it in the aluminum industry. The production according to the Geological Survey was 297,041 long tons. Only about 1 per cent of the total consumption was imported.

*A paper read at the Atlantic City meeting, 1916, of the American Society for Testing Materials.

¹²Ralston: Why Do Minerals Float? *Mining and Scientific Press*, Vol. CXI, No. 17, p. 623 (Oct. 23, 1915).

The Theory of the Corrosion of Steel*

BY LESLIE AITCHISON

The problem of the corrosion of iron has been the subject of a great deal of attention during the past twenty years or so. By means of a very large number of experiments, conducted by various workers, amongst whom may be mentioned Sir William Tilden, Messrs. Walker, Whitney, Moody, and Friend, a number of facts have been accumulated, and two theories have been put forward to account for the actual corrosion of iron. In practically all these cases, the material employed has been pure, or nearly pure iron (*e.g.* the iron foil of Kahlbaum), and in most cases the interest has centered round the attack upon this by pure water (that is, frequently distilled water). At the present time the question is an open one, as to the actual details of the corrosion under these conditions, and the present author does not propose to enter upon that particular field.

Most of the workers have left the theory of the corrosion of steel, which is a material of much greater complexity of structure than iron, rather well alone. This particular problem may be attacked, however, quite apart from the one stated above, and although it may be rather premature to define a concise theory of the corrosion of steels, yet the author feels that certain points might be discussed with advantage, as some fair amount of experimental evidence has accumulated. Acting upon this, the author wishes to put forward, with all modesty, the points which follow, in the hope that, even if they are not acceptable to all those who have thought out this problem, they may give rise to the expression of some other opinions, and so help towards the fixing of some precise idea upon this most interesting subject.

The complex structure of steels, composed as they are almost invariably of carbides imbedded in a matrix of some carbon-free material, renders it almost certain that the action going on in a steel during its corrosion is a galvanic one. This conclusion is not seriously at variance with either of the two theories mentioned above as to the essential nature of corrosion. The large number of galvanic couples present in an ordinary sample of steel can be well imagined, and these couples will consist of the carbide on the one hand, and the ferrite or solid solution on the other. This postulates at once that one of the two constituents will be anodic in its action, and the other cathodic. The anodic one will be attacked by the solution—that is, the material composing the anode will pass from the atomic to the ionic condition.

The other material, acting as the cathode, will remain in the atomic (or molecular) condition, and hence will appear to be unattacked. The intensity of the galvanic action between the two constituents will depend, other things being equal, upon the potential difference between the two constituents with respect to the corrosive liquid which is in contact with the steel.

The carbides in all steels, although of varying chemical composition, will be likely to be possessed of very similar electrical properties, and hence it appears reasonable to assume that the electrolytic solution pressure of all the carbides will be the same, or nearly so. On the other hand, the solid solution, which may range from practically pure iron to an alloy containing many per cents of a second element, will be a material of very varying electrical properties. As a result the electrolytic solution pressure of this constituent will change very considerably from steel to steel, and will in consequence produce a considerable variation in the potential difference existing between the constituents of the steel. As a result the corrosion of the steel should vary a great deal with changes of composition.

All investigators have agreed up to the present in regarding the carbides as being electro-negative (that is, as having positive electro-affinity, or a greater tendency to exist in the molecular than the ionic form). Hence their action should be cathodic, and they should not be attacked by the corrosive liquids. That this is so may be seen by microscopic examination. Two typical structures after corrosion are shown in micrographs Nos. 1 and 3 (Plate 1), the massive carbide being quite obvious in the two cases. The first is a pure carbon steel containing 1.25 per cent of carbon, and the second is a steel containing 0.73 per cent of carbon and 21.5 per cent of tungsten.

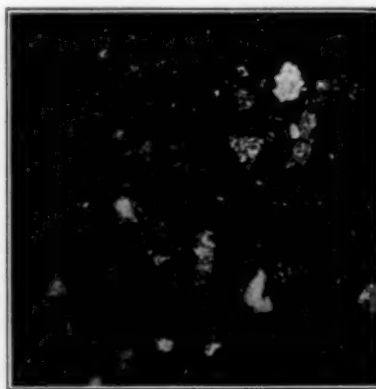
A similar result is obtained by an investigation of the attack of dilute acid upon various steels. By an analysis of the material which goes into solution, and a comparison of this with the compositions of the carbides separated by other methods, it will be found that the carbides are not attacked, and are left in their original form.¹

As a result of this the carbides in steel may be regarded as acting in two different directions. First of all, they act as resisters of corrosion. Since they are not attacked by the corrosive liquids, there should be a

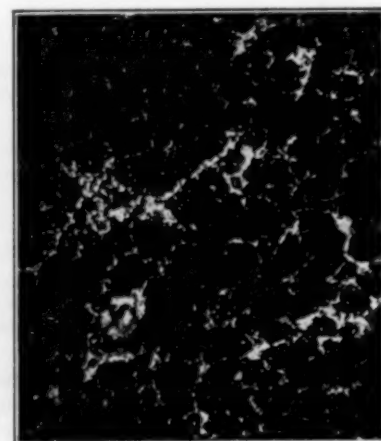
¹CE. author, *Transactions of the Chemical Society*, 1916, Vol. CIX, p. 288, and Arnold and Read, *Journal of The Iron and Steel Institute*, 1910, No. 1, p. 169; 1911, No. 1, p. 249; 1912, No. 1, p. 215; *Journal of the Institution of Mechanical Engineers*, 1914, No. 1, p. 233; 1915, No. 1, p. 247.



MICROPHOTOGRAPH 1—1.25 CARBON STEEL AFTER CORROSION



PHOTOGRAPH 3—PHOTO OF MELT-BAR IRON, CONTAINING 0.07 C, 0.018 SI, 0.09 MN, 0.031 S, 0.010 P. CORRODED IN SODIUM CHLORIDE



MICROPHOTOGRAPH 2—STEEL CONTAINING 0.73 PER CENT CARBON AND 21.5 PER CENT TUNGSTEN. AFTER CORROSION

smaller loss in a steel which is composed largely of carbide than in one which contains only a moderate amount of that constituent. This may be, and probably would be, true, were it not for the other action of the carbides. This is connected with their cathodic action. The intensity of the galvanic action will be to some extent proportional to the area of contact between the two constituents. The more finely divided the carbides, the greater will be the area of the surface of contact; and also the larger the quantity of carbide the greater the available number of surfaces of action.

That this is true may be seen from the figures of Table I. The first pair of results demonstrate the second action, of increasing the carbide, whilst the remaining ones show the first action—that is, of increasing the fineness or the state of division of the carbide. This latter is the normal result of the addition of small proportions of a third element (that is, one besides iron and carbon) to steel.

These three pieces of evidence—the microscopic, the analytical by sulphuric acid, and the effect upon the corrosion—may be taken as conclusive in proving that the carbides act throughout as cathodes. The rest of the material then becomes the anode in the various galvanic couples present in the material. As stated above, this residue of the steel is practically always solid solution. In the case of ferrite, the solution is extremely dilute, sufficiently so for the ferrite, to be termed pure iron, while in other cases there may be as much as 12 or 15 per cent of a second element.

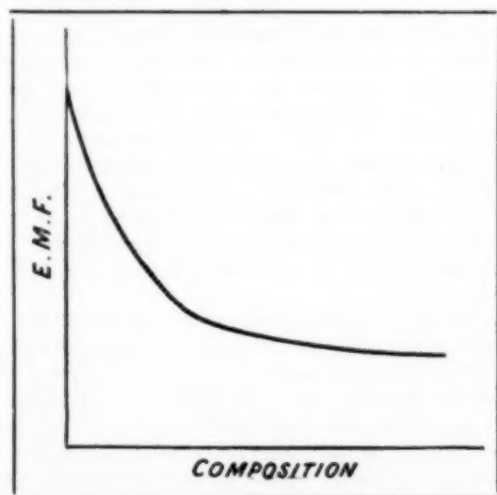


FIG. 1.—GENERAL TYPE OF CURVE GIVEN BY A SOLID SOLUTION

Considering the ferrite alone, two cases arise. First of all, there is the common one, in which the ferrite is present in contact with some carbide and acts as the anode in a galvanic couple.

This case is perfectly simple, the action coming about in consequence of the solution pressure of the iron (the

electro-affinity of iron—i.e., the potential of the metal against a normal ionic solution of its own ions—is—0.063 volt, iron being one of the metals which have a greater tendency to exist in the ionic than in the atomic condition). The negative electro-affinity in the case of the iron, and the positive (assumed) in the case of the carbide, produce all the essentials for galvanic action.

The other case is that of a relatively pure metal—e.g., bar iron—in which practically the whole of the material is composed of crystals of ferrite. As is well known, this material does corrode, and fairly rapidly too. The corrosion on the part of the ferrite in this case has been explained by the galvanic theory, on the assumption that the various grains of the metal have somewhat different solution pressures in consequence of the variation in the orientation of the different crystals. Also the presence of different degrees of mechanical strain in the various crystals is invoked as an explanation of this.

It appears possible, however, that neither of these explanations is necessary, in view of the more accurate knowledge that we possess of the structure of pure metals. Many workers have demonstrated the existence of a material in between the crystals of a metal, which has properties quite different from those of the adjacent crystals. The theories that have been advanced as to the nature of this material need not concern the present discussion, since they all have a point of agreement in that they admit the material to be amorphous.²

The orientation of the adjacent grains being different, there exists in this intergranular volume a material having the orientation of neither. It has been shown by various workers that the properties of an amorphous metal are very different from those of the same metal in the crystalline condition. Amongst other things, it has been made very probably true, that an amorphous substance is possessed of a very different solution pressure from that of the crystalline substance. It has been definitely established frequently, that a worked material has a much greater solution pressure than an unworked one;³ and as the amorphous layer in between the crystals has a relatively close similarity to a worked material, it is not unreasonable to imagine that the solution pressure of this layer is greater than that of the adjacent crystals. Lüdtke⁴ has shown that mirror silver (which is in the strained or worked condition) will show a potential difference of as much as 0.1 volt when coupled with ordinary silver in dilute acids, and Andrews⁵ has found that the strained and unstrained portions of a wrought iron shaft gave a difference of potential of 0.016 volt, in a solution of sodium chloride.

Whichever phase has the greater solution pressure, the result of the existence of a potential difference will be galvanic action, and hence corrosion. This galvanic action would be between the intercrystalline material on the one hand, and the crystals of ferrite on the other. Either of these may be the positive member of the couple, and lose weight. In a perfectly annealed specimen, in which there is but little mechanical strain, it is probable that the action will be confined to that between the ferrite and the cement. If there is any potential difference, however, between the crystal grains due to any cause, then this will add to the effect, and the total corrosion will be the sum of the two actions. It is just possible, though improbable, that the solution pressure of the cement may lie midway between that of the more positive and the more negative grains of ferrite, in

TABLE I

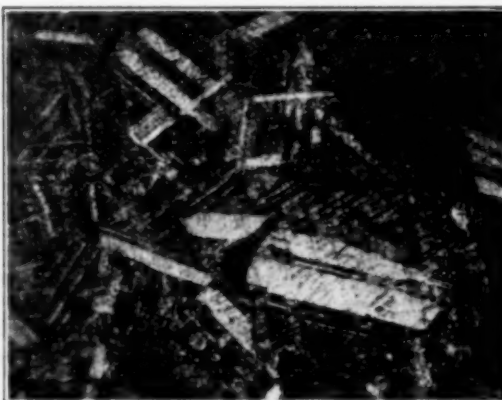
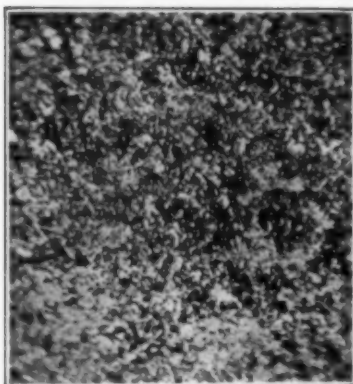
Carbon, per Cent	Other Element, per Cent	LOSS OF WEIGHT IN		
		3 per Cent Sodium Chloride Solution	Tap-Water	10 per Cent Sulphuric Acid
0.50	.....	0.992	0.88	4.57
0.80	.....	1.196	0.92	10.82
0.74	W 2.36	1.54	0.97	8.42
0.73	Co 2.68	1.55	0.94	5.12
0.63	V 0.71	1.73	0.90	8.05

²CF. Rosenhain and Ewen, *Journal of the Institute of Metals*, 1912, No. 2, p. 149; 1913, No. 2, p. 119; and Humphrey, *Iron and Steel Institute*; Carnegie Scholarship Memoirs, 1913, Vol. V, p. 86.

³C. E. Fawcitt, *Journal of the Society of Chemical Industry*, 1906, Vol. XXV, p. 113.

⁴*Annals of Physical Chemistry*, (2) 50, p. 678.

⁵*Proceedings of the Institution of Civil Engineers*, 1894, Vol. CXVIII, p. 10.



MICROPHOTOGRAPH 4—NON CORROSIVE CHROMIUM STEEL

MICROPHOTOGRAPH 5—TWIN CRYSTAL STRUCTURE AS REVEALED BY CORROSION

MICROPHOTOGRAPH 6—0.89 PER CENT CARBON STEEL, AFTER CORROSION

which instance the action of the cement will be anodic in one case and cathodic in another.

Taking the simplest case, namely, the one in which the ferrite is roughly at the same potential throughout, and the intergranular cement at another, then there should be an action developed at the junction of the two substances. The action may not be confined to this face of contact, but will proceed at a maximum rate on that plane. The result should then be that the lines of junction of the crystal show this more intense action, and the evidence should take the form of a relatively deep pit sunk round the crystals. That this evidence is to hand may be seen from the photograph No. 3 (Plate 1), which shows a melted bar iron, having the following composition: carbon 0.07 per cent; silicon 0.018 per cent; manganese 0.09 per cent; sulphur 0.031 per cent; phosphorus 0.010 per cent, after undergoing corrosion in sodium chloride. This theory would account more or less completely for the corrosion of a pure metal.

Passing on to the question of solid solutions, several very interesting points arise at once. Assuming that the action in the case of steel containing carbide and solid solution is similar to that in those consisting of carbide and ferrite, that is, galvanic with the carbide as cathode, it should be evident that the controlling factor in this instance will be the solution pressure of the solid solution, and this will vary with its composition.

The solid solution found in steels have very various compositions, and these have been determined indirectly by Arnold and Read,⁴ and directly by the author.⁵

The results obtained are of interest, and show that in the case of molybdenum, vanadium and tungsten, these elements do not enter into the solid solution until a relatively high percentage of the element is present. At first the tungsten, vanadium and molybdenum are associated entirely with the carbon, and form a part of the carbide. In the case of vanadium, the "saturation" percentage of the carbide is about 5.4, for tungsten about 11.7, and for molybdenum about 19.0. Below these percentages these elements are not found in the solid solution. As a result, the concentration of the solid solution for these elements, even after they do find their way into this constituent, is never very high.

In the case of chromium, this element appears in both carbide and solid solution from the start, and hence the solid solution is much more concentrated in chromium at lower percentages than for any of the previous elements. Nickel behaves in a way just the opposite of vanadium and molybdenum. In the case of that element the carbide is found to be free from nickel until the steel contains more than 8 per cent of nickel. Prior to this the

solid solution receives all the nickel, and in consequence is more concentrated at lower percentages than that found in any of the other alloys.

Up to the present our knowledge of the actual electromotive force curves of these alloys of iron with vanadium, tungsten, molybdenum, etc., is not very great, but the general type of curve provided by a solid solution is well known. In general, it is a logarithmic curve of the form indicated in Fig. 1.

It will be granted that in all the alloys designed to resist corrosion, it will be necessary for the solution pressure (as reflected in the electromotive force) of the solid solution to undergo some considerable change from that of iron, in order that the difference of potential between the solid solution and the carbides shall be sufficiently small as to minimize corrosive action. From the electromotive-force curve it should be evident that there is no sudden change of solution pressure in the alloys forming the solid solution, and that in consequence it will be necessary for the solid solution to become relatively concentrated in the alloying element before the required change of solution pressure can be accomplished.

The corollary to this is surely that there is only likely to be any diminution of corrosion if the new element finds its way into the solid solution early in the series, and also becomes present in reasonable proportions. For any element that goes into solid solution in the steel a small percentage is not likely to be of the slightest value in resisting corrosion. That this view is true may be seen from the following cases.

The author has examined the influence of composition upon the corrosion of steels by determining the loss of weight experienced in various liquids by steels containing carbon only, and carbon with varying percentages of tungsten, vanadium, chromium, cobalt, molybdenum, copper, nickel and manganese.⁶ The results of these experiments show that very few steels containing a third element have any advantage to offer over those containing merely iron and carbon.

The most conspicuous exceptions are the steels containing a high percentage of chromium. The corrosion curve for these alloys is shown in Fig. 2, and it will be seen that it is only in those alloys where there is a good deal of chromium that any improvement occurs. As was stated above, in these steels the chromium is found in both the carbide and the solid solution; from the smallest percentages and the composition of the solid solutions for the steels whose corrosion was shown in Fig. 2 are given in Fig. 3. There it will be seen that the solid solution does contain a reasonably high per-

⁴Loc. cit.

⁵Transactions of the Chemical Society, 1915, Vol. CVII, p. 1531, and 1916, p. 288.

⁶CF. author, Transactions of the Faraday Society, 1915, Vol. XI, No. 1 and No. 11, 1916, and Transactions of the Chemical Society, 1915, Vol. CVII, p. 1531.

centage of chromium in those alloys which resist corrosive attacks.

Nickel steels are another series of materials which have a definite resistant action toward corrosive media, and in this case the conditions are very similar to those holding in the case of chromium. In these steels the

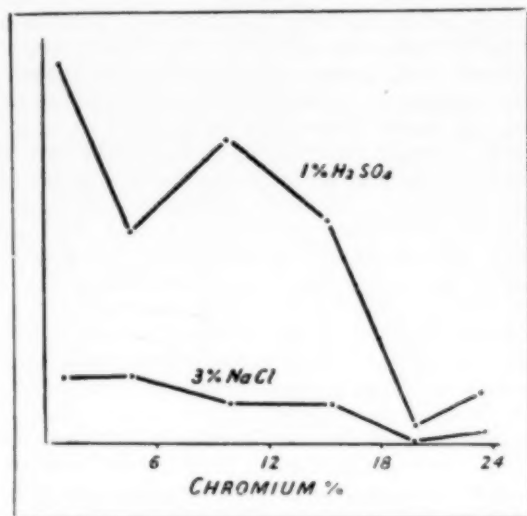


FIG. 2—CORROSION CURVE FOR CHROMIUM STEELS

nickel does not enter the carbide to any extent until more than 8 per cent is present, and hence there is produced a solid solution which contains a reasonably large percentage of this element. Thus in the two best-known examples of anti-corrosive steel the conditions demanded by theoretical consideration are fulfilled.

Yet another example may be put forward. In the steels containing cobalt there is found to be a fall of corrosion with an increase in the percentage of the cobalt. This is remarkable in one sense, because in the steels containing the higher percentages of cobalt the carbides had decomposed and precipitated graphite, a material calculated to cause a violent increase of corrosion if the solid solution has a suitable solution pressure. This increase of corrosion, however, does not take place, and this can only be due to the reluctance of the solid solution to act in an anodic manner. As the percentage of cobalt in the solid solution is found to be quite high, this is not surprising if the theory of the influence of electromotive force be allowed.

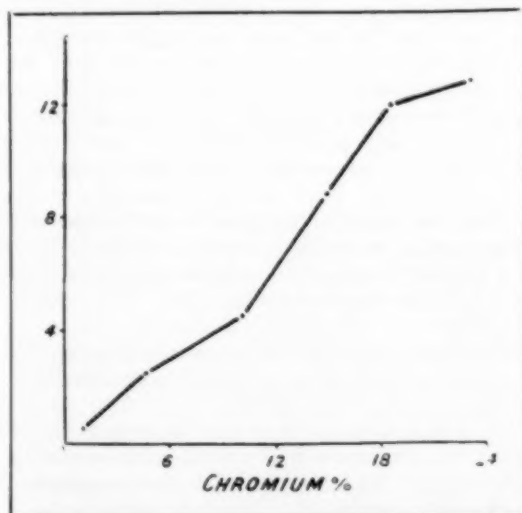


FIG. 3—SHOWING CHROMIUM PER CENT IN SOLID SOLUTION AGAINST CHROMIUM PER CENT IN STEEL

Another case is that of the vanadium steels. The curves for the corrosion of these steels are shown in Fig. 4, and it will be seen that there is an increase in the corrosion up to the steel containing 5.84 per cent of vanadium. After that the corrodibility decreases very appreciably. This is what might be expected in view of the composition of the solid solution. No vanadium is to be found in the solid solution up to the saturation point of the carbide, which is about 5.4 per cent of vanadium in the steel. At 5.84 per cent the solid solution is found to contain 1 per cent of vanadium, at 10.3 per cent it has 3.8 per cent and at 13.45 per cent as much as 7.2 per cent. Hence some distinct influence upon the electromotive force might be expected in consequence of the change of composition. If this change of solution pressure has resulted, then there will be a fall of corrosion, such as is actually found to happen.

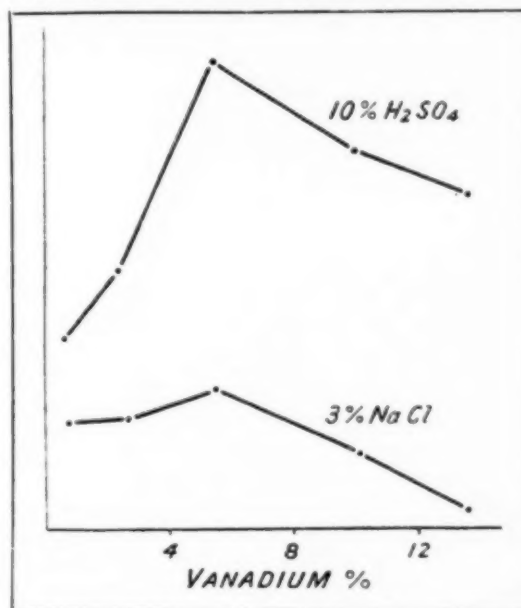


FIG. 4—CORROSION CURVE FOR VANADIUM STEELS

In the other steels examined—*e.g.*, those containing molybdenum and tungsten—there is no resistance to corrosion to be found. The compositions of the solid solutions in these cases show that there is never a formation of anything approaching a concentrated solution. In the molybdenum steels, the one containing 20.7 per cent of molybdenum has a solid solution in which the percentage of molybdenum is about 2.2. In the tungsten steels there is no tungsten to be found in the solid solution up to about 12 per cent, and beyond that only a small proportion, since the tungsten associates itself with the carbide part as both a double carbide of iron and tungsten, and also as a tungstide of iron.⁹ As a result one would not expect that these steels—*i.e.*, containing molybdenum or tungsten—would have any great resistance to corrosion, and this is found to be the case. These experiments all appear to support the theory that the corrosion of a steel is determined mainly by the solution pressure of the solid solution which the steel contains.

The microstructure of these ferro-alloys are also a powerful support of this same theory. The idea has been held for a long time that non-homogeneity in a steel is the primary factor in producing corrosion. This may be correct within certain limits, and given a satisfactory definition of homogeneity, but it is generally assumed in consequence of this idea, that a steel possessed of a complex structure is bound to be corrosive.

⁹Arnold and Read, *Journal of the Institution of Mechanical Engineers*, 1914, p. 223.

This view can no longer be held in face of the structure of the chromium steels that resist corrosion so successfully. The structure of a non-corrosive chromium steel is shown in micrograph No. 4, and it may be seen at once that this steel is quite the reverse of homogeneous, being composed of a very intimate mixture of solid solution and carbide. Here the number of possible galvanic couples per square centimeter of exposed surface is enormous, and everything that could be an aid to corrosion is apparently present. Yet there is no corrosion in weakly attacking media. This can only be due to a lack of power to go into solution on the part of the solid solution—that it, to a negligibly small solution pressure with respect to these media.

Again, take the case of a material of conspicuous chemical homogeneity—the bar iron illustrated in photograph No. 3. Here there is corrosion to an appreciable extent, and this can only be due to a difference of solution pressure among the constituents of the material, as stated above.

A further example may be quoted, that of a solid solution in which twinning of the crystals is present. The microstructure revealed by corrosion in this case is illustrated in micrograph No. 5, and this steel corroded to a very considerable extent. In this case there could be no lack of chemical homogeneity, the only difference between the various parts of the crystals being one of orientation, which would be reflected by a variation of the solution pressure. Yet the mere fact of twinning does not necessarily produce a corrosive solid solution, for some of the nickel steels containing a considerable percentage of nickel have twinned crystals in abundance, but yet only corrode very slightly. Surely these facts support the theory that the solution pressure of the solid solution is the important factor in deciding the corrosion or non-corrosion of a steel.

Following upon the action first of carbides and then of solid solutions (including ferrite) comes the behavior of pearlite—the remaining constituent of steels. This component in the structure of steels is, of course, a mixture in definite proportions of ferrite (or solid solution) and a carbide (simple or complex). Two actions are possible with respect to this constituent—it may act either as a mixture, or as a whole. Both these opinions have been held. Viewing the matter from the point of view of the solution pressure of the constituents, it is a little difficult to see how the pearlite can act as a separate simple constituent. The potential of a eutectic, or a mixture, is that of the constituent having the greater solution pressure (that is, the one showing the greater tendency to become ionic), and in the case of pearlite this undoubtedly is the ferrite. If, then, the pearlite be acting as a whole, it should corrode in accordance with the potential difference set up between itself and the neighboring component, which is the large areas of the ferrite. But if the pearlite be regarded as a whole, then the solution pressure of the pearlite and of the ferrite will be the same, or almost the same. Hence there should be no corrosion. Also, if there were corrosion, then there should be a preferential attack upon either the ferrite or upon the pearlite.

Taking the other view, that the pearlite acts not as a whole, but as a mixture of ferrite and carbide, then the corrosion proceeds in accordance with the usual potential difference set up between these two constituents. This will mean that in any particular grain containing, *e.g.*, ferrite and pearlite, the two components of the galvanic couple will be the carbide on the one hand, and the ferrite forming the body of the grain on the other. Hence, as the whole of the ferrite in the grain is part of the same electrical unit, whether it belongs to the pearlite or to the ferrite, the anodic action should take

place all over the ferritic surface exposed to the corrosive liquid. In this way the ferrite will dissolve all over the surface of the grain, and the carbide will be unattacked.

If a series of pearlitic steels of different carbon content be corroded, and then examined microscopically, it will be found that the resulting structures are almost indistinguishable one from the other. In no case, after an attack of about ten days, can the pearlite structure be observed, and, except for the attacks at the crystal boundaries present in a bar iron and absent in the steels, the pearlitic steels all present the appearance of a corroded iron. The carbide has disappeared, unless a fairly large piece is present when it is left standing in a field composed apparently of badly pitted and corroded ferrite. There is no trace of a separate area of attack of ferrite in pearlite, and it is not possible to distinguish between a steel containing 0.4 per cent of carbon, and one with 0.9 per cent. A typical structure is that shown in micrograph No. 6, a steel with 0.89 per cent of carbon, after corrosion. This can only mean that the ferrite is attacked throughout, whether in the free ferrite areas or in those of pearlite.

The carbides will not have been attacked, this having been proved by many experiments quoted above, and hence their disappearance from the steel can only be due to mechanical means. This, of course, is quite a probable explanation of the action which has taken place, the ferrite being attacked by the corrosive liquid and dissolved away. This removes the support which held the carbide in position, and allows it to fall out during the washing which must necessarily precede microscopic examination after corrosion. The presence of the loose carbide on the surface of a corroded sample that has not been disturbed is usually fairly obvious. If the carbide is massive, it is like to be rooted more deeply in the mass, and hence on light corrosion is not removed.

This accounts for the structure of the steel shown in microphotograph 1, in which the carbide of the crystal boundaries (the cementite) remains clear and unattacked, while that of the pearlite, which normally occupies the body of the crystal, has disappeared. In some of the alloy steels which contained pearlite, and were examined, the corrosive action had not gone far enough to remove all the carbide of the pearlite from its matrix, and traces of the pearlite structure might be still seen in the resulting microsection.

The conclusions to be drawn from the above may be summarized as follows:

(1) That the corrosion of a steel takes place purely by the action of the ferrite or the solid solution.

(2) That the action upon pure ferrite may be due entirely to the potential difference set up in consequence of the different solution pressures of the grains of the metal and the inter-granular cement, it being probable that this latter is possessed of a greater electromotive force.

(3) That the percentage of the third element added to iron and carbon in steels must be sufficiently great to produce a fairly high percentage in the solid solution, if there is to be any beneficial effect from the use of this element.

(4) That the electromotive force of the solid solution with respect to the corrosive liquid is the deciding factor in the corrosion of a steel.

(5) That the pearlite in a steel does not corrode as a whole, but as a mixture of ferrite and cementite, the disappearance of the latter being due to mechanical, and not to chemical action.

(6) That carbides are not decomposed by ordinary corrosive agents, and that they act merely as cathodes to the anode of the ferrite or solid solution.

Concentration and Flotation of Lead Ores in Southeast Missouri

(Editorial Correspondence)

General

The region of disseminated lead ores in Southeast Missouri is the oldest of the large lead-producing districts in the United States. Production from ores in the lower Bonne Terre dolomite is recorded as early as 1869, though earlier production was made from shallow surface pockets. The principal towns of the district are Bonne Terre, Desloge, St. Francois and Flat River, and the producing area is included within a radius of five miles from the vicinity of Desloge-St. Francois. The operating companies are the Federal Lead Co., St. Louis Smelting & Refining Co., Desloge Consolidated Lead Co., and the St. Joseph Lead Co., which also controls the Doe Run Lead Co. To the managers and technical staffs of these companies we are indebted for many courtesies extended and for information on recent concentrating practice in the district.

Six concentrating mills are operated by the four concerns named. A seventh will be in operation this Fall when the new 2500-ton mill of the Federal Lead Co. will be completed. Further addition to the gross mill capacity of the district will result from changes in flow-sheet and equipment at the St. Louis company's mill which will treat 4000 tons per day. The various mills and their approximate daily capacities are listed below.

Name of Company	Mill Capacity Tons in 24 Hr.
Federal Lead Company	5,000
St. Joseph Lead Company, Bonne Terre	2,100
St. Joseph Lead Company, Leadwood	1,900
St. Joseph Lead Company, Rivermines	4,200
St. Louis Smelting & Refining Company	2,500
Desloge Consolidated Lead Company	1,800
Total	17,500

Similarity in the nature and occurrence of the ore on the different properties gives rise to practical uniformity in the methods of concentration, so that except for a few minor variations the milling methods bear a close resemblance to each other. This is true not only of past practice but also in the changes and improvements that are being introduced. The district being comparatively small and compact and the conditions reasonably uniform, the problems of the several companies are similar, varying mainly in degree. This accounts for the general use of the Hancock jig, the gradual adoption of the Butchart table or system of riffing, and the similarity in flotation equipment and practice at all mills.

Crushing and Grinding

The mills are usually erected adjacent to working shafts and the coarse-breaking plant is housed in the mill structure. In other cases run-of-mine ore is crushed at isolated shafts and the crushed ore transported to the mills. Gyratory crushers in large and medium sizes find favor for primary and secondary crushing and are generally adopted. The well known advantages of this type of breaker in handling a large tonnage of ore that is not too wet and sticky, with favorable power consumption and labor attendance, make it a desirable machine where run-of-mine does not come in too large pieces.

A departure from the general use of gyratories, however, is being made at the new coarse-crushing plant of the St. Louis mill, where a Traylor jaw breaker, 30 in. by 60 in., is being installed. The St. Louis mill was built in 1900 to treat 1200 tons of ore per day, but is now handling 2500 tons, with a prospect of 4000 tons when certain changes are made. The weak point in the

system, even at the lower tonnage, was the gyratory equipment which had insufficient capacity on run-of-mine ore, since many of the rocks were too large to be nipped. Capacity could have been increased with the present equipment by screening out the fine, but even then the large pieces would give trouble. It became practically necessary, therefore, either to build a new crushing plant with coarse breakers large enough to handle the big rocks, or remove the fine by screening and crush the oversize to say 4 in. or 5 in. for the present gyratories. A large gyratory could have been used, but in order to handle the large size feed its capacity would have to be unnecessarily great. Consequently the jaw crusher was adopted for primary work, since it would take larger size rock than a gyratory, considering equal capacities for the two machines, and also permit the continued use of the present crushing plant. The large opening of the jaw crusher was the decisive factor in its selection.

At the Federal mill gyratories are used as primary crushers to about 3½ in. and are followed by Symons 48-in. disc crushers giving a ¼-in. product. Similar equipment will be used at the same company's new mill. Where run-of-mine comes unusually large, a good sequence of crushing machines would be jaw breaker, gyratory, disc crusher and rolls.

Rolls are generally used for fine crushing and re-grinding, and at two of the mills, the Bonne Terre which is the oldest in the district, and the Desloge, the old Cornish geared rolls are still in use. The first introduction of the modern ball-mill for regrinding is being made at the Rivermines mill of the St. Joseph company, where an 8-ft. diameter Marcy mill operated by a 200-hp. motor is being placed. This machine will be used for regrinding certain screen oversizes and jig middlings and will be substituted for rolls. The installation is of an experimental nature to determine the efficiency and economy of the modern mill, and its further use will depend on the results obtained from its operation.

Screen-Sizing and Jigging

Screen-sizing is not done on as elaborate a scale as it was before the Hancock jig displaced the Harz, and only one product is now prepared, the limiting sizes being generally 9 and 2 mm. Two types of screens are in use for this work—trommels for both coarse and fine separation, and flat shaking screens, the latter being used in some mills for 2-mm. separation. Most of the trommels are cylindrical, but a few of hexagonal form with horizontal shafts are still in use at one mill for fine work. The tendency, however, to adopt the flat shaking screen of the Ferraris type in place of trommels for screening fine sizes, is in line with the claims of some authorities for the advantages of flat screens. The elimination of undersize grains is more readily accomplished due to lack of interference in their progress across the screen; and more frequent opportunities are afforded the particles to pass through the apertures by reason of frequent changes of position during their travel.

At one of the mills jig feed is prepared by drag classifiers which receive the undersize of 9-mm. trommels. In this case the fine material from the drag is prepared for table and flotation treatment.

As stated before, the Hancock jig is used in all the mills, having entirely displaced the Harz type. Its advantages are well known, but may be briefly reviewed. It will be apparent from the remarks on screening that jigging is done without close sizing, the limits being 9 and 2 mm. The ability of the Hancock jig to effect a separation of mineral according to specific gravity,

practically regardless of size, has made it possible to dispense with the long trains of trommels which formerly were necessary to size the feed for Harz jigs. Further, the Hancock requires less floor space than a number of Harz jigs of equal capacity; it uses very much less water and consumes less power.

The grade of jig feed will range from 3 per cent to 5 per cent lead, and the tailing will run about 0.7 per cent. The escape of fine mineral in the tailing formerly involved a loss which is now obviated by the flotation process. Jig tailings are dewatered either by means of a wheel scoop or by discharging over a screen, and the slimy water is added to other slime pulps and thickened for flotation.

Changes in Table Concentration

In table concentration the two most notable tendencies throughout the district are the abandonment of close classification and the general adoption of the Butchart system of riffing.¹

In table feed the particles range in size from 2 mm. downward, being the undersize of a 2-mm. screen or the overflow of a drag classifier. Formerly this pulp was hydraulically classified into a number of products for sand and slime table treatment, but the present practice consists in desliming the minus 2-mm. pulp, making separation at a point as near 150-mesh as possible. The portion minus 2-mm. and plus 150-mesh is then distributed to sand tables without further classification and the minus 150-mesh grade is in some cases distributed to slime tables or directly thickened for flotation.

Among the desliming devices, which are of local design, may be mentioned the Delano, which is in process of patenting by L. A. Delano, superintendent of the Bonne Terre mill of the St. Joseph Company. Designed to make a separation at 150-mesh, this device has shown high efficiency in practice, yielding 96 per cent minus 150-mesh in the overflow and 93 per cent plus 150-mesh in the underflow.

With the Butchart system of riffing, hydraulic classification other than desliming is unnecessary. The point at which the slime separation is made must be determined for each ore; but once determined, an unclassified feed is tabled successfully. The capacity of a table under the new system of riffing is greatly increased over the old, and water requirement is much less. At the Bonne Terre mill eighteen tables re-riffed according to the new system are treating a slightly larger tonnage than was formerly handled on fifty-two tables with other riffing, showing an increase in capacity of about three times. At the same mill, also, all jig and table concentrates are combined and re-treated over tables with Butchart riffles. The combined concentrates are separated at about 150-mesh into fine and coarse grades by a Delano deslimer, and re-treated over separate tables. The fine yields a product containing 80 per cent lead, and 75 per cent of the concentrate is finer than 200-mesh. The net effect of this re-treatment is to raise the grade of shipped concentrate from 62 per cent lead to from 75 per cent to 77 per cent.

Another factor in the success of the new system of riffing is the means for rapidly separating the stratified mineral without overloading a cleaning zone. It is also reported that large variations in the rate of feed can be tolerated, up to 10 tons per day, without requiring adjustment of the table.

A notable effect of the changes in classification and table treatment is the reduction in quantity of mill water used. Where the changes have not yet been

made, and the old systems still prevail, it is observed that the slime thickening equipment ahead of flotation is overburdened with an excess of water.

General Practice of Flotation

Flotation is practised at all the mills in the Lead Belt, and as might be expected in a district where conditions at the several mills are similar, the methods employed and results obtained are quite uniform. The average tonnage treated by flotation is from 12 per cent to 15 per cent of the ore milled, or between 2000 and 2500 tons per day. Some of this tonnage represents a former waste, and part of it was concentrated on vanners or canvas plants, which have since been abandoned.

It is customary to collect all slime pulps from jig and table tailings, classifier overflows, etc., and combine them into a flow to Dorr thickeners, where flotation feed is prepared. No acid or heat is employed at any of the mills, nor are chemical addition agents of any kind necessary. The water used in milling is pumped from the mines, and owing to the limestone and dolomite formations from which it comes it is very hard. The same oil is used at all mills, known as No. 2 creosote, prepared by the oil department of the Cleveland-Cliffs Iron Company. This is probably a mixture of wood creosote and other oils, and is used as received. The cost is about 14 cents per gallon, and consumption varies from 0.5 to 0.75 lb. per ton of feed.

Three types of flotation machines are in use: Minerals Separation and Janney agitation machines, and air cells like the Callow. The first two types are used for the main treatment, and their tailings are re-treated in air cells without further addition of oil. The only instance of re-cleaning flotation concentrate is at the Federal mill, where the froth from an air cell is re-treated in a single-cell Janney machine.

Most of the agitation machines are composed of sixteen cells, all provided with settling and flotation compartments. An exception to this general rule is the twenty-four-cell Minerals Separation machine at the St. Louis mill, two cells of which are used for mixing and agitation only, with twenty-two yielding a froth. With one or two exceptions all machines are belt-driven and require from 4 to 4½ hp. per cell. It is customary to use small pumps to deliver the oil to the machines, adding it at every second or third cell.

The grade of flotation feed will range from 2.5 per cent to 3 per cent lead. Concentrates from agitation machines contain from 65 per cent to 45 per cent lead, ranging downward from the first compartment to the last. The product of the air cells which re-treat tailings from the agitation machines is lower in grade, running from 20 per cent to 40 per cent lead, according to the material treated. Final tailing contains from 0.2 per cent to 0.5 per cent lead. All flotation concentrates are combined into one product, not only from the individual cells of the agitation machines, but also from the latter and the air cells. This gives a final product containing from 47 per cent to 52 per cent lead.

In the operation of the air cells a steady supply of air at from 5 to 7 lb. pressure, delivered by a blower specially provided for the purpose, has been found essential to good work. Where blowers have not been installed air is taken from the high-pressure air line through a pressure-reducing valve, but the result is not as satisfactory as with air from a low-pressure blower. The latter gives a steadier supply than the other method, and makes the work of the cell more uniform.

Handling Flotation Concentrate

The dewatering of concentrates is accomplished by first thickening in Dorr thickeners. At some of the

¹Transactions, Amer. Inst. Min. Eng., LI, 405; also this journal, May, 1915, p. 332.

mills an Oliver filter is used to further dewater the Dorr product, while at others the Dorr discharge is dried in shallow wooden tanks with steam coils in the bottom. The latter expedient is resorted to even if the filter is used, since it has been impossible to obtain a filter cake with less than 14 per cent moisture, whereas the smelters set a limit of not more than 7 per cent. Steam drying, therefore, appears at the present time to be a necessity in this district.

The general effect of flotation has been to increase the saving of lead, simplify the flow-sheet of the mills, and in some cases, to eliminate canvas tables, vanners or other tables for concentrating slime. Reciprocating tables are still in use in some mills for slime concentration, and in such cases the tailings from these tables are floated. The re-treatment of old slime tailing dumps is another development made possible by flotation. At the Rivermines mill an old slime pond is being reclaimed by hydraulicking and pumping to Dorr thickeners, where the pulp is combined with current slime tailings. The hydraulic water lines and pumps are operated from rafts on which the machinery is housed, the rafts floating in natural sumps in the pond to which the slime pulp gravitates as it is dislodged from the surrounding banks by the hydraulic streams. Pumps are belt-driven from motors, and flexible connections are made between the pumps and permanent pipe lines along the edge of the pond.

The consistency of flotation feed varies somewhat at the different mills, but in general is three parts water to one of solids. At the St. Louis mill the ratio is 6:1, which is the thinnest pulp treated. It is at this plant also that the twenty-four-cell machine is used, and while an oil consumption slightly higher than the average is admitted, a lower tailing, 0.2 per cent lead, is claimed.

The foregoing memoranda on flotation are general for the district. More detail of operation can be given on the work of the St. Joseph company at the Bonne Terre mill, where no other form of slime concentration is practised.

Flotation at the Bonne Terre Mill

The overflow from the Delano deslimers, together with other waste slimes from concentrating machines, representing about 15 per cent of the daily mill feed of 2100 tons, is thickened in five Dorr thickeners, four of which are 40 ft. by 8 ft. and one 44 ft. by 6 ft. They run at the rate of one revolution in ten minutes, and the discharged pulp has a water:solids ratio of $3\frac{1}{2}$ or 3:1. A screen test of the discharged solids will show from 95 per cent to 97 per cent finer than 150-mesh and from 88 per cent to 90 per cent finer than 200-mesh.

The thickened pulp flows to a sixteen-cell Minerals Separation machine, the impellers of which run at 300 r.p.m. The power requirement is 72 hp. Oil is added at every other agitation compartment, beginning with the first. Formerly the entire quantity of oil was added at the first agitator but experience showed that subsequent additions were necessary before treatment was complete, so the practice was adopted of distributing the oil to successive compartments as needed to make a good recovery. A slight difference is noted in the results obtained in winter and summer, the latter showing an improvement, but the difference is not sufficient to warrant the expense of heating the pulp. The consumption of oil is 0.7 lb. per ton of feed.

Froths from all cells are combined into one product, even though the grade of concentrate from the head compartments is higher than that from the other end of the machine. These products will range, respectively, from 65 per cent to 50 per cent lead. The tailing is elevated by centrifugal pump to an air cell for final treatment, and a concentrate containing from 30 per cent to

40 per cent lead is obtained and combined with the froth from the agitation machine. The average grade of the mixture is 52 per cent lead, and final tailing contains from 0.35 per cent to 0.5 per cent lead. Air is supplied to the final machine at 7 lb. pressure.

The flotation concentrate flows to a belt and bucket elevator, which raises it to a Dorr thickener, 38 ft. by 6 ft., running at the slow rate of one revolution in thirty minutes. Thickener feed contains 90 per cent moisture and discharge 40 per cent. Other means were tried for raising the pulp to the thickener, but the elevator was found best since it aided in breaking the froth when the buckets discharged their load. Pumps aggravated the frothy condition of the pulp and had to be abandoned. The froth is very persistent, and every means must be utilized to break it or avoid increasing it. Thus a spray of clean water is used over the receiving well of the thickener, and the incoming pulp is discharged above the surface, as this was found preferable to a submerged discharge. The use of oily water in the spray cannot be tolerated. Even with all precautions the accumulation of considerable dense froth on the surface of the thickener cannot be prevented, and from time to time it is removed by a hoe and again delivered to the elevator.

Filtration of Flotation Concentrate

The thickened pulp with 40 per cent moisture is further dewatered on an Oliver filter, which yields a cake $\frac{1}{8}$ to $\frac{3}{16}$ in. thick containing from 14 per cent to 15 per cent moisture. Persistent efforts and experiments have failed to lower the moisture in the filter cake below this point. On one occasion the entire filter was housed in a tight covering, and dry air at a temperature of 175 deg. Fahr. was blown into the inclosure in the hope of reducing the moisture content of the cake. The result was almost negative, for the moisture was not lowered appreciably below that obtained under normal conditions of operation. Heating the pulp with live steam also was tried, and while this did not effect a decrease in the moisture content of the cake, it had the unexpected and desirable effect of almost doubling the capacity of the filter, which up to that time was scarcely equal to the service demanded.

Since the smelters set a limit of 7 per cent moisture in concentrates, it is necessary to dry the filter product, as already explained, in tanks with steam coils in the bottom. As these tanks must be filled and emptied by hand, additional expense and delay in marketing are entailed by the process.

Oliver filters are in use at several of the mills and are being installed at others. The filter is a desirable machine, even if it cannot deliver a commercially dry product from this particular type of mineral slime, most of which is finer than 200-mesh. The drying of a 40 per cent moisture pulp in steam boxes is an expensive process, besides being slow, requiring additional labor and holding a large amount of concentrate in the process. The intermediate step of filtering to reduce moisture by 25 per cent, or 62.5 per cent of the total, must be more economical than attempting to remove the entire amount by heating.

Asphalt Industry in 1915.—According to the Geological Survey the asphalt industry enjoyed a prosperous year in 1915. Natural asphalt produced amounted to 75,751 short tons, valued at \$526,490, which was 5 per cent less than in 1914. The manufactured asphalt, however, made from domestic petroleum residues was 664,503 short tons, valued at \$4,715,583, or a gain of 84 per cent over 1914. There was also 388,318 short tons made from petroleum imported from Mexico.

Cost Accounting in the Construction and Operation of a Copper Smelter—IV

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In previous instalments* of this series methods have been presented at considerable length for gathering information necessary for an adequate compilation of costs and accounts covering the construction and operation of a copper smelter. Lists of accounts into which it is necessary to segregate the expenditures have also been given. The discussion so far has been primarily devoted to subjects connected with accounts covering the money-cost of construction, repairs and reconstruction of the various mechanical and structural units comprising the complicated machine known as a modern copper smelter, e.g., buildings, furnaces, tracks and flues. Therefore, the more extensive subject of accounting for operating expenses has been mentioned only in passing; a list of useful operating accounts coördinating with the construction and repair accounts has been given, and it has been indicated how the account books, machinery and personnel of the construction cost-keeping bureau can be utilized by the operating departments.

It should again be emphasized that all time-cards, warehouse and shop orders should bear tersely worded descriptions of the particular detail of the job to which they refer, in addition to the appropriate account and sub-number. Only in this manner can the demands of both the cost-keeper and the auditor be fulfilled. The auditor could tell the manager the total cost of operating the blast-furnaces for any fiscal period, but the aid of the cost-keeper and metallurgist is required to discover the cost per ton of smelting rabble cleanings from the McDougall furnaces. Even their best efforts will be totally unavailing to produce important details of cost if the necessary information has not been gathered and noted on the spot and properly filed for future reference.

Progress in the metallurgical art results largely from an improvement of the details of a process rather than from a revolutionary change in the method itself, and in nearly all cases a revision of detailed practice is a success or failure in exactly the same measure as it decreases or increases the cost of the operation. How, then, can the manager be enabled properly to judge whether or not a variation in the routine would be desirable, if he is in ignorance of the cost of the old practice, and cannot discover the expense of the new?

Distribution of "Non-Productive" and General-Commodity Costs

The necessity for clear and adequate notations on all operating charges is particularly evident in such "non-productive" units as the power house department, which, as has been previously noted in the listing of operating accounts, cannot usually be adequately subdivided in the ordinary accounting system. The word "non-productive" is somewhat a misnomer, as the power house produces such valuable commodities as power, light, heat and blast. It is commonly used in accountant's parlance inasmuch as such departments are outside the continuous chain of smelting operations between ore and ingot; serving all, as need arises. The cost of operating the power house, therefore, becomes an "expense" to be absorbed by the "productive" departments.

The problem of determining the correct value and

proper estimation of the consumption of such widely used commodities is one of the most difficult for the management to solve, and becomes a mere matter of guesswork in many instances. However, if the proper care and attention has been bestowed upon the detailed labor and material charges day by day, the cost-clerks will be able to divide the sum total of the bookkeeper's account into parts representing the cost of producing high-pressure water, converter air, steam for heating and the dozen other kinds of power developed. Assuming that the plant is equipped with adequate meters, the reports of the power-house timekeeper will show the amount of each class of power "at the switchboard," whereupon the cost per horsepower, kilowatt, gallon or cubic foot can be immediately established. As demonstrated previously, these prices should evidently be fixed for a certain fiscal period and revised only at such long intervals (as experience with the profit-and-loss account will direct), in order to enable one to make rational comparisons of smelting costs, should they carry power charges.

Given the necessary data, then, the procedure will so far be comparatively simple, but the cost-keeper would seem to be in ignorance of what becomes of the power when it leaves the power house. Bear in mind, however, that time-cards for all large machines will be found on file giving a continuous history of their operations, as well as daily reports to the power-house clerk covering the operations of small tools and isolated equipment. Taking a concrete illustration, the amount of air consumed per hour per converter and its cost will be readily determinable—converter air is generated in a particular type of engine and is piped directly to the converters and used by them alone. But the electric power necessary for tilting is not so easy to fix—the driving motors are on a general power circuit supplying a 100-hp. motor at each converter operating 1 per cent of its time at 50 per cent overload, cranes with 300 hp. in motors operating 60 per cent of the time at 20 per cent capacity, motors for casting machines, ventilators, elevators, and so on, each operating under different conditions and load factors.

The total electricity furnished this circuit might have been metered at the substation, but the final destination will be at first a matter for the chief engineer's or master mechanic's best judgment. No time should be lost after operations are running along smoothly to check up and revise such estimates by a painstaking determination of the actual average power consumption of all machines, furnaces and departments. If properly made, the quantities so determined can be maintained as a fixed charge per hour on the time-card of every machine, and the sum total of all such for the month should balance within limits with the total output of the power-house. Any large discrepancy will be a signal for an investigation; the error will be corrected, or the leak quickly stopped. The time of a well-trained engineer could not be better invested than in continually watching the power distribution throughout a large smelter. The prime object of his labors would not be the construction of a nice power balance-sheet, but the detection and elimination of leaks; one large one discovered and corrected will save his salary for an indefinite period. Under his care it would be unnecessary to compress 800 cu. ft. of blast for every 100 blown through the tuyeres of the blast furnace, a condition reported by a recent metallurgical text.

All commodities used in the concentrating, smelting and refining processes should be as carefully watched and accounted for as the power accounts alluded to above. Water, for instance, costing thousands of dollars to develop, store, pump and deliver should not be

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turned loose at the rate of 50,000,000 gal. a day to the tender mercies of table and jig, sluice and cooling jacket without at least knowing how much of it each machine needs, and then seeing to it that one machine operative does not extravagantly waste another's portion. Such knowledge and supervision is the first step toward efficiency because it will lead naturally and quickly into comparative tests of alternative types of apparatus with the development of new schemes for saving money by the conservation of even such an ordinary commodity as water.

Special Attention Required for Gathering Information

The usual method in vogue in smelters of requiring straw-bosses to make out the time-cards would be entirely inadequate for the prosecution of the system here outlined. Owing to a press of more important duties connected with "getting the copper" he will fill in his reports and make up the time-cards in the hastiest manner—shortly falling into the habit of jotting down merely the account number and sub-letter, failing even to properly distribute the time in case his men are working on more than one subdivision. Time-keeping and clerical work should not be expected of a foreman any more than responsible supervision should be asked of a clerk.

The method outlined for gathering information during construction should therefore be followed after the plant has been blown in; and, in general, it would be a wise policy to retain as many of the trained construction staff as will be necessary to handle the simpler and much more steady routine of operation.

The timekeeper assigned to each department should make a tour early in the shift, gathering the time-cards from the straw-bosses, noting at the proper place in his loose-leaf note-book the detailed information necessary to adequately describe the kind of work each man is doing and all unusual conditions which may surround the work. From the shift-boss and sampler he notes the number and time of machines, furnaces, converters or other large machines in operation; he makes a rough estimate of the amount of raw material (such as ore) in the bins and finished material (such as concentrates) ready for delivery, visits various indicating meters and makes periodical notations of their readings and changes and preserves charts on recording meters.

Such tours for inspection and information are repeated at intervals of two hours exactly as outlined previously in this discussion. During the day the timekeeper visits the warehouse and shops to examine the charges on current orders and makes out the time-cards for workmen and machines, in general, carrying out the routine learned during construction.

One of the duties to be performed early in the shift is to make a statement of conditions in the department at the beginning of the shift, appending necessary explanatory remarks, which is inspected carefully and initiated by the department foreman before being forwarded to the general foreman's office. The statements from all departments are here collated and condensed into a general tabulation of operating conditions for the information of the management. This general statement also bears information as to the amount of major supplies consumed and principal products produced, gleaned from reports of the transportation, unloading and tramming departments and of various scalemen placed at proper parts of the plant. Such a summary statement of operations, shorn of numerous minor details, is given in Table I.

Accounting of Metal in Process

A consideration of our dictum that all commodities

TABLE I—GENERAL SMELTER REPORT

McDougall Roaster Department.			
Number running	8		
Charges:			
Fine concentrates	491	tons	
Lime rock	117	tons	
Fine screenings	7	tons	
Fuel used:			
Coal	4400	lbs.	
Oil	50	gals.	
Tons per square foot of hearth	0.07		
Time lost	10½	furnace hours	
Gas Producer Department			
Number running	21		
Nut coal to producers	274	tons	
Coal to boiler house:			
Nut	46	tons	
Fine screenings	82	tons	
Coal used per ton smelted	0.6	tons	
Analysis of gas:			
H ₂	10.0	per cent	
CH ₄	3.0		
C ₂ H ₄	0.5		
N ₂	58.0		
CO	23.0		
CO ₂	5.0		
O ₂	0.5		
Caloric power	148	B.t.u.-cu.ft.	
Reverberatory Department			
Number of furnaces running	3		
Number of taps	36		
Number of charges	15		
Charges:			
Calceine	388	tons	
Flue dust	125	tons	
Fine lime rock	5	tons	
Tons per square foot of hearth	0.26		
Time lost	4¾	furnace hours	
Blast Furnace Department			
Number running	5		
Taps	38		
Car loads charged	1,978		
Materials charged:			
First class ore	538	tons	
Coarse concentrates	421	tons	
Custom ore	137	tons	
Converter slag	316	tons	
Limestone	676	tons	
Coke	414	tons equals	
	10	per cent of whole	
Tons per square foot of hearth	6.6		
Time lost	6	furnace hours	
Converter Department			
Number of charges	19		
Converters changed	4		
Number of crews	5		
Cranes operating	2½	converter hrs.	
Time lost	67		
Pots of slag cast	266,000	lbs.	
Copper made			

used in the concentrating and smelting process should be carefully watched and accounted for, leads us naturally to the thought that an accounting of the actual metal in process should show strikingly valuable information as to the operations in general, and the efficiency of small units in particular. This is entirely beside the idea held in some large organizations that each department should operate as a separate business concern, paying for what it uses and selling what it produces; and above all, operating at a profit. Evidently, under such a system, a knowledge of the metal consumption and production of the department as a whole is absolutely essential. The routine for the production of such information will now be outlined.

The concentrating department stands at the head of those necessary to turn ore into metal. Its receipts are low-grade ore from various mines and localities. The *quantity* of this ore is had from the transportation and unloading department reports showing the weight, point of origin and point of unloading of each carload or parcel of material. The consumption of these receipts is determined roughly by the daily receipts, less the estimates of the timekeepers of the amount of this material in the bins, and is adjusted monthly to accord with the careful inventory estimates made by the engineering staff of all quantities of ore in the concentrator bins, storage bins, stock piles, bedding system and any other place where material is held preliminary to treatment. The *quality* of the ore is a matter for the sampler and the chemist to determine. In case the ore comes from the company's own mines, the sampling and assaying is usually done at the point of origin. Foreign and custom ores are to be sampled in the ap-

proved manner. A discussion of the various arrangements of automatic machinery for such large quantities of material is beside the scope of this paper, for it has been excellently handled elsewhere by expert engineers who have given this particular branch of concentration their whole time and attention.

The metal accountant is enabled by a judicious use of this information at his disposal (i.e., inventory, receipts and analyses) to compute the consumption of the concentrator of copper, gold, silver, sulphur, iron, silica, alumina, lime, zinc, lead and any other substance which is a benefit or a detriment to the subsequent operations and which must, therefore, be either converted or eliminated to the fullest possible extent.

The production of the concentrator falls into four main classes, to wit, coarse concentrates, fine concentrates, slimes and tailings, each of which may possibly be differentiated as to the section of the mill which produced them, size, value or other characteristic. Leaving such variations out of account, the specific case of the disposition of coarse concentrates will best describe the general method of accounting for the production.

Specific Case of Coarse Concentrates

The coarse concentrates are laundered directly to the storage bins and sampled en route by automatic machines diverting the whole stream at regular intervals for a small period of time into a small tank placed nearby. This sample is collected by the sampling department, drained, weighed, dried, further cut down, ground and prepared for analysis in an approved manner. The analysis by the laboratory is forwarded to the metallurgist and the concentrator foreman, together with information as to the point of origin of the sample and the shift which produced it, and is scrutinized by them in the light of past performances and the ideal in mind to be attained.

The quantity of coarse concentrates is derived from the scaleman's reports, who records the weight, point of origin and destination of each carload drawn from these bins. The total of these weights should check with the amount of concentrates produced as derived from the weight of the sample obtained per shift; which, being gathered by automatic machinery, will represent a certain percentage of the amount of solid matter passing the sampler during its operation. At monthly intervals the engineers will make careful estimates of the quantity of concentrates on hand in each bin; these inventories, the scale weights of material trammed and the sample weights will allow the metal accountant to compute the production of coarse concentrates month by month.

Note that the metal accountant does not receive the daily routine analyses of materials in process, made as noted above. Instead he usually receives merely the analysis of the "monthly sample" representing the average of all coarse concentrates produced during the month. This sample is made up in the sampling department by preserving the same small fraction of each shift sample; this sample being proportional to the production for that shift. At the end of the month all of this material combined will represent a weighted average of the production for the month. The analysis when multiplied by the gross monthly production will give the quantity of each metal or oxide produced in this particular commodity.

The daily samples of the coarse concentrates may vary within limits around 12 per cent copper; the variation is a matter of concern for metallurgist and millman, but the metal accountant gets only the analysis of the monthly sample, which may read:

Moisture	5.75	per cent
Copper	12.22	per cent of the dried sample
Silver	3.90	ounces per ton
Gold	0.018	ounces per ton
SiO ₂	20.73	per cent
FeO	33.25	per cent
S	33.75	per cent
Al ₂ O ₃	4.40	per cent
CaO	0.28	per cent

From a consideration of his various weights the metal accountant arrives at the conclusion that 18,020 tons of coarse concentrates have been produced, which figure as follows:

Dry weight	33,968,691	lb.	s
Copper	4,154,638	lb.	
Silver	66,245	ounce	
Gold	311.5	ounces	
SiO ₂	7,037,466	lb.	
FeO	11,315,604	lb.	
S	11,475,725	lb.	
Al ₂ O ₃	1,493,861	lb.	
CaO	96,941	lb.	

This represents the total production as coarse concentrates for the period in question, and these figures are placed on his balance sheet in the proper places.

In a similar manner the fine concentrates, slimes and tailings are automatically sampled before reaching the storage bin, the resulting sample being a measure of both the quantity and quality of the product. In the case of fine concentrates, the weights of the carloads trammed from the bins to the calcine or other departments will serve as a check upon the production. In case the slimes are retreated, the metal in the slime plant is carefully accounted for in a similar manner as in the concentrating department, and these figures will serve as a check against slime production in the concentrator. Slime ponds and slime storage piles may be inventoried by quantity estimation by the civil engineering staff at intervals of twelve months in case the accumulation is very large, although, in general, monthly estimates will involve no more work in the totality. For estimates of the amount of tailings, reliance must be placed on the weights of the product of the automatic samplers; a check may be had by figuring all material not otherwise accounted for as tailings. Such a proceeding should be followed with circumspection, as it is liable to lead to numerous inconsistencies in the final figures for the various substances; but worse, it will cover up a multitude of sins of omission.

Accounting of Furnace Materials and Products

More attention is usually paid to the metal accounting of the furnace departments' receipts than elsewhere in the plant, for even in the most carelessly run plant, smooth working of the furnaces demands a properly balanced and weighed charge. The blast-furnace storage bins, for instance, may contain sections for first-class ore, second-class ore, custom ore, lime rock, briquettes and coke, each of which is weighed and sampled before delivery and which is drawn out in definitely weighed quantities in making up the furnace charges. With the aid of the monthly inventory, this material can be closely accounted for, as can also such intermediate and retreated products as concentrates, calcine barrings, converter and refinery slag, matte and smelter cleanings.

After once entering the furnace, however, the adequate tracing of the material is not so easy. The ordinary products are matte, slag, flue-dust and fume. Of these the matte is most simple to estimate. The quality is determined by filling one or two small ladles from the stream when tapping a pot of matte from the furnace or settler, and forwarding the buttons cast from each furnace to the laboratory for analysis. The quantity is determined by taking the gross and tare

weight of each ladle as it goes to the converter department, either on a platform or track scale, or if handled overhead, by automatic scales hung from the crane. The weight of matte skulls shaken out of the ladles for retreatment is found similarly.

If granulated, the slag is sampled, estimated and analyzed similarly to the procedure for concentrator tailings. If handled in pots, the sampling is done in the same manner as sampling matte, and the contents can be weighed on the way to the dump.

Difficulties of Estimating Flue-Dust and Fume

The estimation of flue-dust and fume is not so easy and in most cases the figures used are little more than guesses "by difference." Metallurgists have recently become very much alive to the fact that a close scrutiny of feasible methods of reducing the quantity of these elusive substances will pay handsome dividends, not only directly in values and retreatment charges saved, but indirectly in expensive "smoke suits" and damages averted.

By flue-dust is meant the finely divided solid matter carried in suspension from the furnace top by the more or less swiftly moving gases and which quickly settles as the velocity and carrying power of the smoke is reduced when passing through the larger flues leading from the furnace department. These flues are provided with hopper bottoms and large quantities of dust

vice should be used which will extract a representative portion of the passing gases without condensation of the fume, or loss of the very fine dust. A thorough study of the varying velocities of the different portions of the gas stream is also necessary in order that the curves drawn by the draft gage and recording thermometer may be transformed into cubic feet per minute.

Analytical skill and engineering ability of a high order is necessary to properly sample and estimate the conditions existing in the upper part of the flue system from dust chamber to top of chimney, but its expenditure will amply repay the company whose policy is sufficiently enlightened to realize the offensive and defensive value of accurate, complete and trustworthy information as to conditions in this part of the smelter. Flue and chimney jobs are usually dreaded by members of the staff, yet under proper design and management these units can become a veritable gold mine, and under the opposite conditions a theft of profits and a public nuisance.

Metallurgical Accountant's Balance-Sheet

The method of accounting for all furnace departments (roasters, reverberatories and blast-furnaces) is quite similar each to each, and need not be further dwelt upon. As a general illustration of a page from the accountant's balance-sheet, that covering operations of a McDougall roasting department is appended in Table II. It appears here in a condensed form from

TABLE II—McDOUGALL ROASTING DEPARTMENT
MATERIALS CHARGED

	Dry Weight, Lb.	Copper, Lb.	CaO, Lb.	Al ₂ O ₃ , Lb.	Sulphur, Lb.	FeO, Lb.	SiO ₂ , Lb.	Gold, Oz.	Silver, Oz.
Fine concentrates	28,207,111	2,492,687	95,333	1,507,286	10,125,066	10,361,299	5,113,580	291.9	42,938.5
Fine ore, etc.	740,563	48,526	1,831	65,701	129,735	128,619	357,605	5.6	800.2
Slimes	928,966	25,462	2,317	189,881	41,792	40,896	550,005	2.0	504.7
Limestone	1,990,657	987	1,000,146	12,033	5,383	17,422	115,728	0.5	10.9
Total charges	31,867,297	2,567,662	1,099,627	1,774,901	10,301,976	10,548,236	6,136,918	300.0	44,254.3
MATERIALS PRODUCED									
Calceine	21,071,385	2,091,250	1,055,289	1,276,327	1,875,079	8,533,180	4,538,806	262.3	37,170.2
Cleanings	171,904	13,823	564	6,179	7,024	107,710	10,691	1.7	230.3
Flue-dust	3,587,248	328,598	17,729	279,234	652,717	805,274	907,832	35.7	5,822.5
Total production	24,830,537	2,433,641	1,073,582	1,561,740	2,534,820	9,446,164	5,457,329	299.7	43,223.0
Losses	7,036,760	134,021						0.3	1,031.3
Per cent loss	22.1%	5.21%						0.10%	2.33%

GENERAL NOTATIONS

Furnace days worked	228.5
Tons treated per furnace day	69.7
Pounds per square foot hearth area per furnace day	149
Cost per ton	\$0.65
Disposition of product:	

are drawn from them every day to be charged and re-smelted in the reverberatory furnaces. Weighing and sampling this dust is a matter of routine. Inspection holes at intervals in the flue walls and roof are utilized by the engineers to make monthly estimates of the material in the flue, whence a balance on the quantity of dust deposited may be had. Incidentally, a monthly estimate of flue-dust in the system will prevent any overloading with accompanying disastrous results to supporting beams and columns.

Little of the fume and not all of the finest dust is deposited before the gases join smoke from other departments, or enter the main dust chamber. At the point of junction it will be necessary to sample and measure the quantity of gases from each department in order to fix the origin of the very fine material deposited in the main dust chamber or precipitation plant, as well as the gases and solids discharged from the main stack. A very carefully designed sampling de-

what would be desirable in practice, as ordinarily more than four different classes of materials are charged.

However, it is extensive enough to illustrate the form of such balance-sheets and will indicate some of the uses to which it may be put. For instance, there is a loss of 134,021 lb. of copper shown. The inquiring eye of the manager will immediately light upon this item. With the metal at a normal price of 15 cents a pound, this represents a value of \$20,000.00; evidently well worth hunting for. Doubtless a considerable proportion of this metal will be found in the fume, deposited in and above the main dust-chamber, and which item does not appear on this balance sheet. Yet, if all the products were accurately sampled and estimated, a roasting department (or any other department, for that matter) should show a true balance between the "treatment" and the "production." This, of course, represents an ideal which is unattainable owing to imperfections in the analytical and other processes involved, yet the aim of the entire technical staff should be to approach this ideally perfect balance more nearly each month. Would any auditor be content with his staff and organization should the money accounts of a cor-

puration, however big, show a leakage of \$20,000 a month; or accept the statement of the bookkeeper that he "thought it represented unavoidable wastage"?

Accounting in the Converter Department

The converter department receives a varied assortment of material which is sampled and weighed before delivery. Matte from the blast-furnaces and reverberatories is charged molten; each ladleful being sampled and weighed as described above. Ore, concentrates, matte skulls and various fluxes are sampled and charged from time to time in weighed boat-loads as the blow progresses. Scrap-copper from the refinery or outside sources used to cool the converter is handled and weighed by the boat. Spillings, accretions, floor-cleanings and other products originating and retreated in this department are not taken into account on the metal balance sheets for obvious reasons; however, a monthly inventory of such material will furnish the necessary information to appear on the balance as "material in process."

The main product of the converter department is, of course, anodes of blister copper. These are sampled by holding a flat, pan-like ladle over the freshly poured anode, catching the minute shot-copper which dances up from the surface during cooling. Anodes from each blow are carefully stacked up, cleaned of projecting fins and weighed over accurate scales as they are trucked into cars for shipment to the refinery. Converter slag is a more bulky product, which is handled and weighed between converter and slag-casting machines as it is transported by the overhead traveling cranes. Sampling is done by thrusting a cold iron rod to the bottom of the ladle and quickly withdrawing it—a thin layer of slag adheres which will easily shell off upon cooling. The gases and fume present the same difficult problem discussed previously and are handled in the same general manner. Converter spittings, accretions and other unfinished products are usually retreated as rapidly as they are formed, by charging them back into a blow, and, therefore, do not need to be analyzed or estimated, with the exception of any balance existing as "material in process" at the regular inventory.

The maintenance of such a system of metal accounting will cause small additional expense to the company. One or two young technical graduates stationed in each department about the works will gather the necessary samples, and in most cases may act as scalemen as well. Considerably more expense will develop upon the laboratory in order to run the necessary analyses; some little time will be required from the civil engineers at the first of each month to make the inventory, and at least one first-class bookkeeper will be required for the clerical work of tabulation. This organization, with the exception of the civil engineers, should be under the direct control of the metallurgist; who, of course, should be directly responsible to the management for the proper technical operation of the processes involved in metal recovery.

Value of the Metal Inventory

Doubtless the greatest value of the metal inventory will be its everlasting demand for perfection. In order that it may measure up to the standard maintained in the clerical department for the money accounts, the closest attention must be paid to the details comprising the basis of the metal accounts. In order that the account may balance, the losses must be located. It will test the cleverest wits to discover the location of some of these losses. But what is more natural than an effort to prevent them or at least curtail the unpreventable to the smallest possible amount? Unprevent-

able losses in large volume should immediately condemn a supposedly successful concentrator or furnace and will institute a vigorous search for a more successful substitute. No line of investigation will be more fruitful of real facts about a furnace process than a close study of the metal and material balances when these are constructed on a scientific basis.

As an actual instance of the value of such studies suggested by the author's experience, a certain concentrator section was guilty of producing what seemed to the metallurgist to be an excessive amount of slime. A squad of samplers and investigators (all young technical men) under the direction of a competent engineer, started out to find where the trouble lay. They investigated the production of slime from the unloading bins to the banner division and showed conclusively that the coarse-crushers directly in front of the ore-storage bins were the greatest offenders. In order to "get the copper" the crusher-men kept their machines choked all the time—in this manner not only cutting down the actual capacity of the crushers but largely increasing the fine produced. In this manner the Blake crusher actually produced a greater amount of fine per ton of material treated than did a Huntington mill. An automatic feeder was then designed and installed to feed each of these large crushers a steady stream of coarse material from which the large proportion of undersize had been removed. The crusher capacity was increased, the operating cost in labor and repairs decreased, and best of all, the amount of slime made by the concentrator showed a sudden and gratifying drop.

Cincinnati, Ohio.

Synopsis of Recent Chemical and Metallurgical Literature

Iron and Steel

Effect of Chromium in Hardening Steel.—Chromium is widely used in special steels, usually with other added elements. Experiments have shown, however, that a chromium steel has self-hardening properties, without the presence of tungsten and that within certain ranges of composition the element chromium has an even greater self-hardening effect than tungsten. Further experiments carried out along this line are described in a paper presented to the Iron and Steel Institute in London by Professors C. A. EDWARDS, J. N. GREENWOOD and H. HIKKAWA.

Previous experiments by Hadfield, Osmond and the present authors, had shown that the rate of cooling determined the self-hardening properties, and considering that marked differences of hardness were obtained at different rates of cooling the author thought it desirable to examine the following conditions: (a) At what critical rate of cooling this self-hardening property becomes manifest, (b) whether there are any variable factors which influence this critical rate, and (c) what is the nature of the thermal change, if any, under the conditions of cooling which produce hardening. In other words, to make a quantitative examination of, and extend upon the facts which were discovered so long ago by Messrs. Hadfield and Osmond.

The composition of the steel used in the experiments was as follows:

	Per Cent
Carbon.....	0.63
Silicon.....	0.07
Manganese.....	0.17
Chromium.....	6.15

The initial temperature to which the pieces were heated was found to have an important bearing on the self-hardening properties and its effect and the rate

of cooling were investigated with the following results.

This property of self-hardening is governed by the rate of cooling.

The critical cooling velocities which produce hardening varies with the initial temperature, being much slower as the temperature is raised. The extent of this variation has been determined for a wide range of temperature.

The appearance of self-hardening coincides with the presence of large quantities of martensite, and a diminution in the magnitude of the carbide thermal change.

The maximum hardness was obtained when the thermal transformation had been entirely prevented, and when this was accomplished the steel was purely martensitic in structure.

While, with the chromium steel which has been used, the cooling rates which produce hardening are extremely slow as compared with those which are obtained in the hardening of carbon steels by quenching, the two operations are fundamentally the same. In other words, a given rate of cooling which might be regarded as slow for carbon steels, really constitutes quenching in the case of some special alloy steels.

The precise cause of an increased initial temperature making the self-hardening more evident is not known with any certainty. The view which the authors provisionally hold at present is, that the chromium carbide (Cr_3C_2), which has been isolated by Professors Arnold and Read, first goes into solution as $(\text{Cr}_3\text{C}_2)_n$, i. e., Cr_3C_2 , and is then progressively dissociated into Cr_3C_2 as the temperature is raised. When the steel is again cooling these molecules only slowly reassociate, and thus the molecular effect of the dissolved chromium carbide is greater as the initial temperature and molecular dissociation increases.

Tungsten and Molybdenum

New Tests for Molybdenum.—In the March issue of the *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, Dr. JAMES MOIR gives some new and sensitive tests for molybdenum. The first relates to the formation of a characteristic blue color which ordinarily appears as a fugitive tint in the first stage of reduction of molybdic acid by nascent hydrogen. The author has improved this test and secures a permanent blue color.

Hydrazine, N_2H_4 , forms in the writer's experience the best reagent for developing the blue color. A solution containing a trace of alkali molybdate when acidified with acetic acid and treated with a little hydrazine sulphate and boiled, rapidly turns deep-blue and retains this color on boiling. Hydroquinone may be used in place of hydrazine with much the same result. An analogous but more remarkable reaction, is that obtained when a slightly acid solution of MoO_3 is treated with potassium iodide (in some excess) and boiled for some time: iodine is slowly liberated and the solution turns blue. The use of phenylhydrazine for reducing molybdenum has been described by Spiegel and Maas (*Berichte*, 1903, p. 513), but the reddish coloration obtained is different and seems to contain phenylhydrazine. Simple hydrazine is an improvement.

The best known sensitive test for molybdenum is that in which the acid solution is treated with sulphocyanide and a tiny piece of zinc added, when a crimson coloration is obtained in a few seconds. If iron is also present the solution becomes blood-red on adding the sulphocyanide, but on adding the zinc this becomes colorless through reduction (to the ferrous condition) and after a few seconds becomes crimson if Mo is present. If the solution is strongly acid the coloration verges to red and is less sensitive; if nearly neutral the coloration

resembles that of permanganate. It is probably due to $\text{Mo}(\text{SCN})_3$. Another modification of the test for Mo in presence of Fe is to add stannous chloride to the acid solution until the yellow color just disappears and then add sulphocyanide.

Another well-known reaction for MoO_3 in the absence of iron consists in adding potassium ferrocyanide. Mineral acid must be present, and a russet-brown precipitate is obtained which still contains hexavalent molybdenum.

In the presence of acetic acid (not mineral acid) tannin (or gallic acid) gives a similar reaction, which has been known for some time. The writer has improved this by substituting pyrogallol or pyrocatechol for tannin. Either of these when added to a molybdic acid solution previously treated with sodium acetate gives a very sensitive orange coloration.

The System Tungsten-Molybdenum.—The following summary of the essential points in a research conducted by FRANK A. FAHRENWALD, is taken from the *June Bulletin of the American Institute of Mining Engineers*. The alloys of tungsten and molybdenum have received little consideration in the past; in fact the author finds but two references in German literature on the subject, and his own studies lead him to differ with previous investigators who believed in the existence of a definite compound between the two metals. The thermal equilibrium diagram is given in Fig. 1.

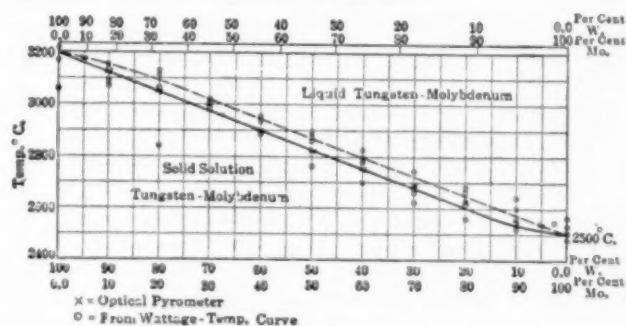


FIG. 1—THERMAL EQUILIBRIUM DIAGRAM

1. By compressing the mixed reduced powders of tungsten and molybdenum into briquets and then heating with an electric current in an atmosphere of hydrogen, alloys of this series were prepared varying in composition from 100 per cent tungsten to 100 per cent molybdenum.

2. The solidus curve for the series was located by means of optical pyrometer temperature measurements and checked by comparing the fusing current with a standardized wattage-temperature curve.

3. The equilibrium diagram for this series shows no critical points, appearing as resistance fluctuations, corresponding to a separation of a new phase. Its construction has been based upon this fact and upon results of microscopical analysis.

4. Curves for hardness, and for equiaxing temperatures, are smoothly convex, being typical of an uninterrupted series of solid solutions (mixed crystals).

5. As a result of thermal and microscopical analysis, the metals tungsten and molybdenum are reported to be completely isomorphous.

6. All alloys of this series are malleable and ductile under proper conditions.

Sulphuric Acid

Roasting and Acid Plants of Braden Copper Co.—In *Teniente Topics* for December, 1915, Mr. JOHN B. WISE publishes a descriptive account of the methods of roasting copper concentrates and producing sulphuric

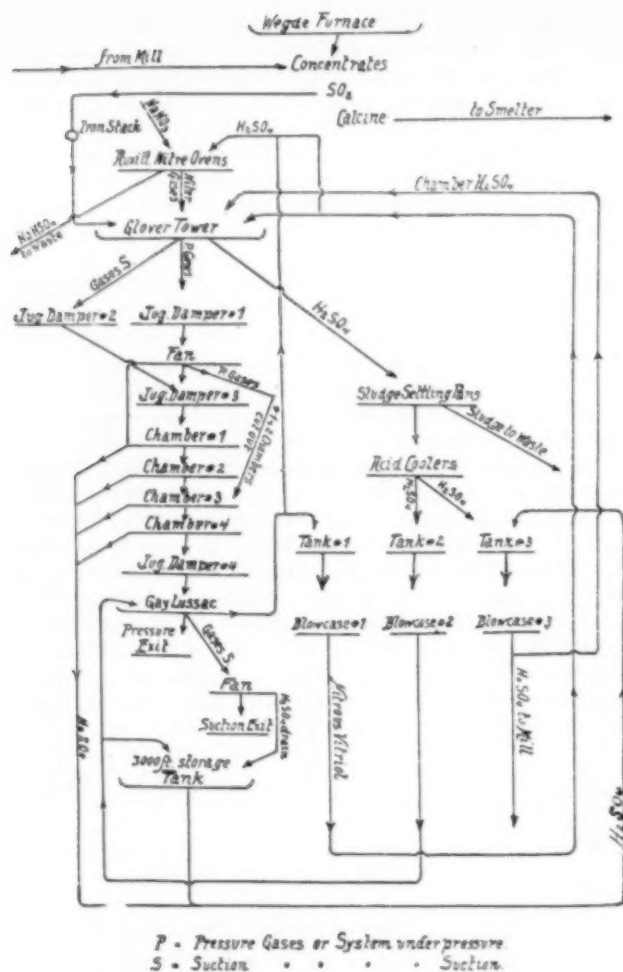


FIG. 2—FLOW-SHEET OF BRADEN ACID PLANT

acid at the works of the Braden Copper Co., Sewell, Chile. A flow-sheet of the Braden acid plant is given in Fig. 2. Wilfley table concentrates are roasted in a Wedge 7-hearth furnace, the feed carrying from 6 per cent to 7 per cent moisture, 16 per cent copper, 13.6 per cent silica, 28.6 per cent iron, and 33.3 per cent sulphur. Hearth temperatures, from 1 to 7 respectively, in degrees Centigrade are 380, 460, 600, 750, 790, 680, 630. The furnace shaft makes one revolution in 3 minutes 20 seconds, and 12 hp. is required to operate the furnace when treating 35 tons of concentrates per 24 hours. The calcine contains about 3 per cent sulphur.

The lead chambers are four in number, each with a volume of 46,750 cu. ft. They are formed of timber framing and 1/8-in. lead sheets. The following table gives certain data on chamber operation.

Chamber No.	Temperature, Deg. C.	Color of Gas	Deg. Baume of Drip
1	80	Gray	51-52
2	75	Light gray	50-51
3	69	Slightly yellow	49-50
4	48	Pale yellow	46-48

The daily production of chamber acid is from 23 to 24 tons at 66 deg. Be. Five tons produced in the Glover tower bring the total to 28 or 29 tons per day. The plant has been in operation for over three years, beginning in March, 1913.

The Barrett Company has contracted with the Lehigh Coke Company for the purchase of its tar and will erect tanks and stills near the coke company's plant at Didier, Pa., in the Lehigh Valley. A loading station will be erected for shipping to the Barrett Company's other plants.

Recent Chemical and Metallurgical Patents

Metallic Alloys

An alloy of copper having certain desirable properties, particularly hardness, is patented by FRANCIS C. FRARY of Minneapolis and STERLING TEMPLE, St. Paul, Minn. The metal is alloyed with one of the alkaline earths, calcium, barium, strontium or magnesium. Such an alloy containing less than 1 per cent of alkaline earth will be harder than pure commercial copper, of high electrical conductivity, and can be made into sound castings. (1,169,392, Jan. 25, 1916.)

The production of sound copper castings in which boron exists as graphite exists in cast iron, is patented by EDWARD D. GLEASON of New York City. It is the primary object of the invention to produce copper containing boron throughout its mass when congealed, and in this respect the invention differs from that relating to the purification of copper by boron, the latter leaving the melt with the slag. The inventor claims copper containing boron material occluded throughout its mass in excess of a trace. (1,169,536, Jan. 25, 1916.)

Chromium Alloys.—A series of chromium alloys for use as electrical resistances are patented by WILBUR H. DRIVER of East Orange, N. J. The patent states that when 5 to 10 per cent of chromium is added to copper an inferior metal is produced, but when 10 to almost 20 per cent of chromium is added, alloys are produced which have a high resistance to oxidation, a high electrical resistance and a low temperature coefficient. With the increase in chromium, however, the workability is decreased, and the 20 per cent chromium alloy is difficult to work. The 10 per cent alloy, however, is stated to work easily, and this is the preferred amount, although from 2 to 20 per cent may be added.

As one example, about 45 parts, by weight, of copper, about 45 parts of nickel and about 10 parts of chromium are fused together in any convenient manner. As another example, about 50 parts, by weight, of nickel, about 30 parts of copper, about 10 parts of manganese, and about 10 parts of chromium are fused. The lowest temperature coefficients have been obtained where the nickel and copper are used in about equal amounts, and as the nickel is increased the alloy becomes harder. But these nickel-copper-chromium alloys, with or without manganese, give very good results, both where the nickel predominates and where the copper predominates. The effect of the addition of chromium to alloys containing nickel and copper, increases as the percentage of the nickel increases. In other words, it seems as though the chromium has a greater effect, for electrical resistance, upon the nickel than upon the copper (1,175,724, March 14, 1916).

Tin

Tin from Chloride.—An apparatus for the reduction of tin and titanium chlorides is patented by FRIEDRICH MEYER and HANS KERSTEIN of Berlin, Germany. The apparatus is in the form of a long tube as shown in Fig. C. The tube shown at the left is for reducing tin chlorides and that shown at the right for reducing titanium chlorides.

In reducing dichloride of tin the tube *b* is omitted. Hydrogen is introduced through tube *C* and molten dichloride of tin through the same tube. Zones *A* and *B* are heated to 250 deg. *C* and zone *C* to a temperature between 600 and 1000 deg. *C*. The dichloride evaporates in zone *C* and is partially reduced to tin, which flows off through *d*. Hydrochloride acid and the excess hydrogen escape from the top of the tube. The dichloride distilling off condenses in the zones *B* and *A* and flows back to *C*, where it is finally reduced to tin.

For the reduction of the tetrachloride to tin the tube *b* must also be used. Tin tetrachloride vapor is admitted through *b* and pure hydrogen through *C*. Zone *C* is again heated to between 600 and 1000 deg. C., zone *B* to 500 to 600 deg. C., and zone *A* to 250 deg. C. The reduction takes place so that at the lower extremity of *b* and zone *B* dichloride is formed, which condenses partly in zone *B* and partly in zone *A*, and descends to *C*. It is there reduced to tin, which flows off through *d*. Any

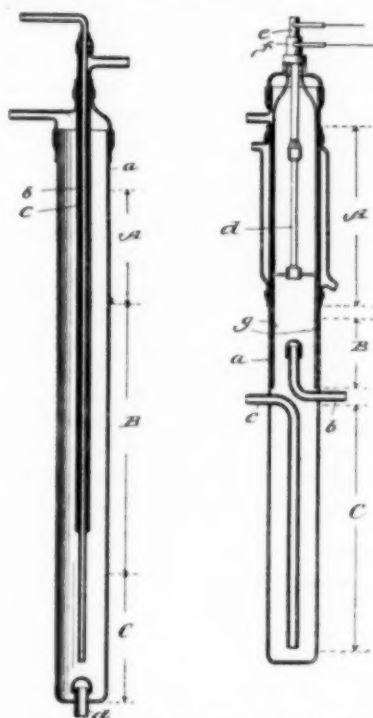
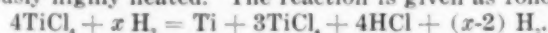


FIG. 1—REDUCTION OF TIN FROM CHLORIDE

dichloride that may have been volatilized, returns through zones *B* and *A* to *C*.

For the reduction of titanium tetrachloride to trichloride the apparatus shown at the right is used. This apparatus is based on the use of process of St. Claire-Deville, consisting of quick chilling of the product previously highly heated. The reaction is given as follows:



In the apparatus titanium tetrachloride is introduced in the form of vapor through tube *b* and pure hydrogen through tube *b*. If it is desired to reduce only to dichloride, zone *C* is kept below 700 deg. C., for reducing down to metallic titanium, a temperature of 800 to 900 deg. C. is used. Zone *B* must be kept at about 500 deg. C., zone *A* is formed by what is known as a Deville tube. A heating device such as a carbon rod is indicated at *d*. Lower leading-in wires are shown at *g*. These also serve as scrapes, for detaching trichloride from the cold wall.

In zone *A* complete conversion into the trichloride takes place. The trichloride drops through *B* to *C*, where it is converted to titanium, titanium chloride, or tetrachloride. Finally, the lower part of *C* will be filled with titanium, while hydrochloric acid and hydrogen escape at the top. The gaseous reducing agent may be a mixture of carbonic oxide and water vapor, instead of hydrogen, and pressure may be used. (1,173,012, Feb. 22, 1916.)

Metallurgical Furnaces

Sulphating Ores Under Pressure.—HENRY B. HOLLAND, of Duluth, Minn., has patented both laboratory and commercial types of furnaces designed for dry sulphating at superatmospheric pressures. Either type of

furnace involves a container for holding and supporting the material treated; means for agitating the material; an outer casing for withstanding superatmospheric pressure; means for introducing the reacting constituents, such as air and SO_2 , into the apparatus; a bleeder valve, and means for introducing and discharging the material to and from the furnace. (1,164,187, Dec. 14, 1915.)

Annealing Furnace.—An annealing furnace designed to utilize coal, coke, oil or gas producer fuel is patented by CHARLES F. KENWORTHY, of Waterbury, Conn. The furnace consists of an annealing chamber, heated from the outside by allowing the products of combustion to pass through an annular chamber surrounding the annealing chamber. Bright metals can in this manner be annealed free from fire or oxidation and do not require subsequent polishing or cleaning. Below the annealing chamber and in communication with it is a liquid chamber. A number of platforms arranged on vertical supports, which are movable up and down and sideways, carry the work to be annealed. A hydraulic piston arrangement moves these platforms from the liquid up into the annealing chamber and then back into the liquid. An automatic valve at the top of the annealing chamber releases suction or pressure and prevents liquid from being drawn up into the annealing chamber. The gas producer may be placed adjacent to the annealing furnace and directly connected to it. Pyrometer thermocouples are joined to the vertical supports at each platform. (1,169,494, Jan. 25, 1916.)

Calcining Furnace.—A furnace designed for heating finely divided or granular carbon is shown in sectional elevation in Fig. 2, being the patented invention of WILLIAM R. CLYMER of Cleveland, Ohio. The calcining chamber 2 extends centrally from top to bottom of the furnace, and is fed with the material to be calcined from a hopper 3. The treated product is removed by screw conveyor 5 and discharged at 7. Surrounding the heating chamber is a tortuous passage 8 communicating with passage 9 which, in turn, is connected with an air supply. Another tortuous passageway 10 is in communication with a fan 12, the latter also being in connection with the calcining chamber by means of duct 13. Passages 8 and 10 merge into a combustion chamber 14 which communicates with passage 15 which ends in a stack or flue 16. The gases given off from the calcining mass in the heating chamber are drawn by the fan and delivered into passage 10 and thence in combustion chamber 14, where they are mingled with air entering through 8. This produces the heat necessary to treat the mass in the chamber 2. As the products of combustion pass through 15 to a point of discharge they give up heat to the material in the upper part of the chamber. As the charge descends in the shaft it will give up heat to the air in passage 8 and thus preheat it for combustion with gas in 14. (1,147,706, July 27, 1915.)

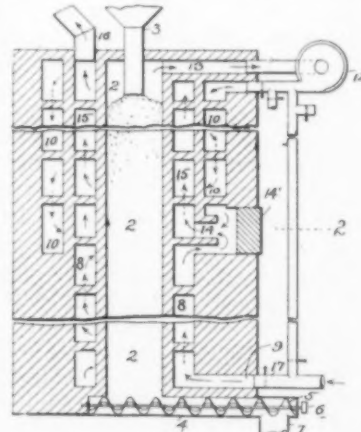


FIG. 2—CALCINING FURNACE

Sintering or Chloridizing Furnace.—A furnace designed to treat ore by roasting in a continuous oper-

ation in unit charges or batches has been patented by IRVEN R. MARGETTES and EARL R. PEMBROKE of Salt Lake City, Utah. It is illustrated in plan in Fig. 3. It consists of a series of covered pans *E*, having hinged

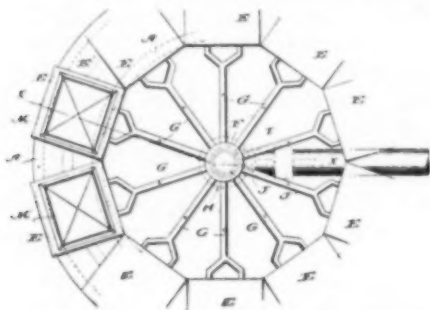


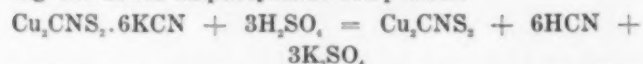
FIG. 3—CHLORIDIZING FURNACE

grate bottoms and designed to carry a charge of ore. Each cover or hood is connected by pipes *G* with a central pipe *F* which has connection with a means of suction or vacuum. The entire series of pans is designed to rotate on supports *A*, and at some point in their travel they pass over a fire box. At other suitable points they receive a charge of material to be treated, and discharge the same after treatment by dropping the hinged bottom. Arrangements are made whereby these operations are performed automatically. In operation a charge of ore, sodium chloride and fuel, or any other desired mixture, is placed in a pan which passes over the firebox. The mixture becomes ignited and the combustion continues in an upward direction after the pan leaves the firebox by reason of the draft induced through the pipes *G* and *F*. After being under suction for a determined period, the pan arrives at a point where its bottom is dropped and the charge is released. After the bottom has again been locked in place another charge is received for treatment. (1,145,329, July 6, 1915.)

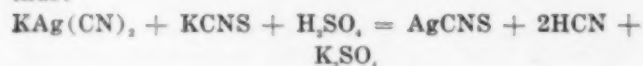
Gold and Silver

Improved Process of Cyaniding.—A method of cyaniding ores to recover not only precious metals but also base metals like copper, and to regenerate cyanide and render foul solutions more efficient, is patented by HARAI R. LAYNG, of Seneca, Cal. In the ordinary cyanidation of ores much cyanide is consumed in the formation of complex cyanogen compounds such as sulphocyanides and double salts thereof with the metal cyanides. Thus silver, copper and other metals enter the solution as sulphocyanides dissolved in cyanide, whereby half the cyanide consumed is due to the formation of sulphocyanides. The presence of such compounds as copper sulphocyanide and potassium sulphocyanide reduces the solvent efficiency of the cyanide solution. The inventor proposes to precipitate the metallic and alkaline sulphocyanides from the solution and recover the metals and cyanogen therein represented.

Solution resulting from the treatment of ore is treated in a sealed vessel with mineral acid, precipitating the metal sulphocyanide compounds.

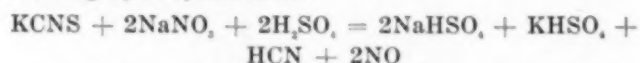


Where the metal is not all in solution as a sulphocyanide but as simple cyanide dissolved in alkaline cyanide, the acidification will precipitate the sulphocyanide thus:



In case the solution contains free sulphocyanide it can be separated if desired by precipitation with cuprous chloride, forming an insoluble compound. In case the solution does not contain free sulphocyanide and contains potassium silver cyanide, some free sulphocyanide may be added to the solution to precipitate silver as a sulphocyanide when acid is added to liberate the cyanogen which would otherwise have been contained in the silver cyanide.

The precipitates thus formed are then treated in a retort with an oxidizing agent such as HNO_3 or NaNO_2 , in the presence of H_2SO_4 , oxidizing the sulphur and forming hydrocyanic acid.



The HCN gas is absorbed in a suitable alkali and the NO gas is oxidized to HNO_3 and absorbed in water. The residue in the retort may be treated as desired to recover the metals. This residue usually contains copper sulphate which may be used in the presence of a reducing agent like SO_2 to precipitate free sulphocyanide from the acidified cyanide solution in the first step of the process. (1,183,086, May 16, 1916.)

Treatment of Anode Slime.—In the recovery of gold and silver from anode slime according to the patented process of FRANCIS C. RYAN, of Hammond, Ind., the feature of the process consists in the removal of certain impurities like arsenic and selenium by converting them into water-soluble compounds which may be removed by leaching. This purifies the material without producing poisonous fumes. The scheme of treatment is shown diagrammatically in Fig. 4. The slime is



FIG. 4—TREATMENT OF ANODE SLIME

roasted with soda ash, converting arsenic and selenium into sodium compounds that may be leached with water. The residue is then roasted with sulphuric acid, converting the metals, with the exception of gold, into sulphates. This material is leached with hot water and filtered, removing the copper and most of the silver, and leaving basic sulphates of bismuth, antimony and tellurium with the gold. The precious metals and copper may then be recovered from the solution and residue in any desired manner. (1,185,005, May 30, 1916.)

New Barometric Condenser

The Ingersoll-Rand Company, 11 Broadway, New York City, is now offering to the trade complete steam condensing plants for all service conditions. This equipment includes the Beyer barometric condenser, for which the company has secured the patent rights, Imperial duplex and Ingersoll-Rogler straight-line, reciprocating, dry vacuum pumps and, where required, Cameron simplex and centrifugal pumps.

The Beyer barometric condenser is of the counter-current type, in which air and cooling water flow in opposite directions. The steam inlet is at the bottom of the condensing vessel, the water inlet above and the air removal opening at the top. The sheets of cooling water overflowing the pool at the inlet point meet the entering steam. The two are brought into intimate contact by conical baffle plates assisting the water to absorb to its full capacity the latent heat of the steam. The non-condensable air liberated in the condensing action rises through the falling water to the removal point at the top, being cooled to practically the temperature of the incoming water. It is also to be noted that ample opportunity is given for the removal of the air content of the water before it mixes with the steam. This not only facilitates the mixing process, but permits the removal of air and vapor at a comparatively low temperature, which is a distinct advantage as the reduced volume saves in vacuum pumpage horse power.

The steam inlet is of large diameter to secure low velocity and is hooded in such a way as to discharge the steam into the center of the condensing vessel. The air removal opening is also of ample area and is protected by a self-draining baffle and trap. This, it is said, positively prevents water being carried over into the vacuum pump.

The hot waste water is discharged through the self-draining tail pipe. This pipe straddles the hot well and rigidly supports the condenser.

The Imperial and Ingersoll-Rogler Vacuum Pumps

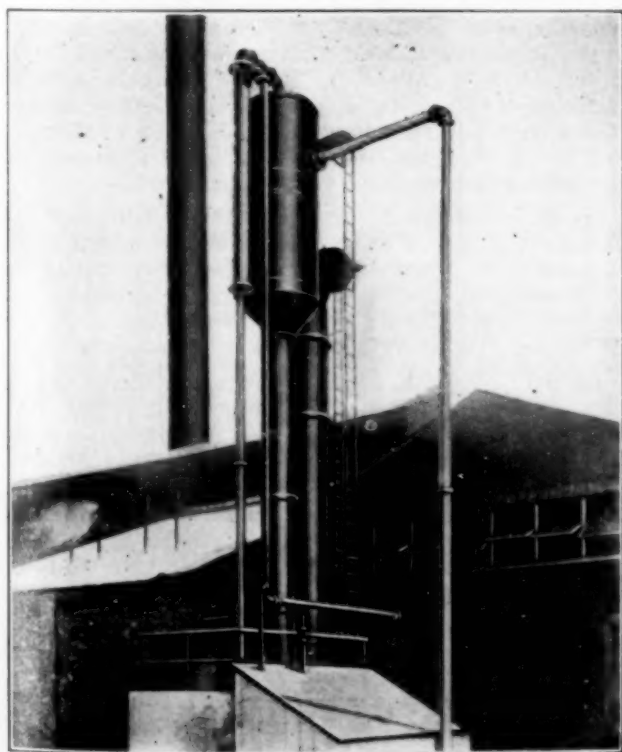


FIG. 1—OUTSIDE VIEW OF BEYER BAROMETRIC CONDENSER

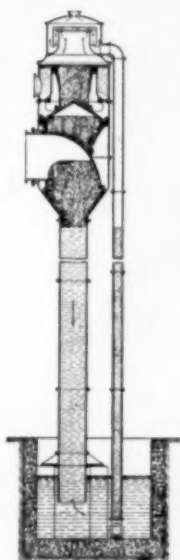


FIG. 2—SECTION OF BEYER BAROMETRIC CONDENSER

are of the manufacturers' standard type. They are high-speed reciprocating machines, wholly enclosed, automatically lubricated and are claimed to effect a floor space saving approximating 50 per cent over the more common slower speed vacuum pumps.

When a water pump is required to elevate cooling water to the condenser head Cameron pumps are provided. These may be either reciprocating or centrifugal, as desired. The Ingersoll-Rand Company, however, emphasizes the fact that, where the level of the cold well is of sufficient height above the hot well, the condenser will lift its own cooling water, dispensing entirely with a water pump.

The vacuum and water pumps, being independently operated, can be regulated to suit varying water temperatures and conditions, and this plant, in addition to its efficiency in general service, is admirably adapted for duty as a central condensing unit serving a number of prime movers.

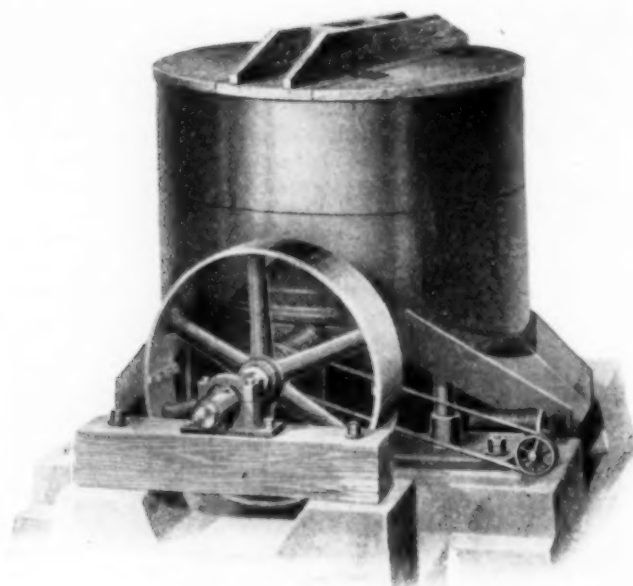
Disc Crushers in Use at the Intermediate Stage

The Symons disc crushers, made by Messrs. Chalmers & Williams of Chicago, Ill., have proven highly economical as intermediate crushers. In most large plants crushing is done in several stages, the first break being made in heavy jaw or gyratory crushers, and the second break was formerly done by smaller jaw or gyratory crushers, or crushing rolls. It is in this second or intermediate stage of crushing where the disc crushers are used.

One of the features is that both discs turn in the same direction at the same speed so that there is practically no abrasion or grinding action between the two discs. The material fed through the spout is immediately distributed by centrifugal force and that portion sufficiently fine is thrown out through the opening between the discs against wearing plates in the hood and discharged.

The range of reduction is large, the product uniform, and the capacity per horsepower very high. The cost of operation, of course, depends upon the material being handled and local conditions. The cost of repairs ranges from under 1/5 cent to about 1/2 cent, the latter being high. In one plant crushing hard gravel the total cost for reducing material from 3 1/2 in. to 3/4 in., including every item of expense connected with operation, was 97 cents per 100 tons.

Another crusher made by the same company is the Symons fine-reduction disc crusher, which is only made in one size. This machine was developed primarily for receiving a feed 2 1/2 in. and finer, and crushing down to 1/4 in. and finer. When used in this way the efficiency is very high and the cost for operation extremely low. It may be operated either wet or dry and the product is very uniform. The New Cornelia Copper Co. of Arizona, recently ordered thirteen of these machines for crushing dry. There will be three units with three crushers in each unit and a fourth unit to be held in reserve. The three units of nine crushers will handle material discharged from gyratory crushers set to 3 1/2 in. and deliver a product all practically 1/4 in. and finer.



SYMONS FINE REDUCTION DISC CRUSHER

These nine crushers will handle 4,000 tons in 16 hours and based upon tests extending over a long period, will not use over 360 hp.

As a result of extensive tests made upon these machines it has been found that by changing the upper disc slightly and the feed opening, material can be handled up to 4 in. ring and reduced at once to $\frac{3}{8}$ in., $\frac{1}{2}$ in. or $\frac{3}{4}$ in. When so operated the capacity is practically all that can be fed into the machine and may be 50 tons per hour and up; the power in no case should exceed 60 hp. and usually would not be over 40 hp.

Personal

Mr. F. L. Craddock has been appointed manager of the New York office of the Pfaudler Company, Rochester, N. Y., and Mr. R. B. Kilmer has been appointed manager of the Chicago office.

Mr. George W. Fraser, formerly superintendent of the smelting department of the Arizona Copper Co. at Clifton, Ariz., has been appointed superintendent of smelting at the plant of the American Copper Syndicate, Ltd., at Aroa, Venezuela. He left for his new post July 6.

Mr. Robert C. Gemmel, general manager of the Utah Copper Co., has been elected a director of the company. Mr. John M. Hayes, assistant cashier at Salt Lake City, has been appointed treasurer.

Mr. S. S. Jones has resigned his position as superintendent for the Tom Reed Gold Mining Co. in the Oatman district, Arizona. The entire management of the company changed on June 1 and practically all of the new staff are former employees of the Gold Road Co.

Mr. Bernard MacDonald has moved his office from Los Angeles to 715 Mills Building, El Paso, Texas, where he will continue his professional work. At present he is collaborating with the engineering staff of the Alvarado Mining & Milling Co. in designs for increasing the capacity of that company's mill at Paranal, Chihuahua, from 400 to 600 tons per day. The machinery has been ordered and will be installed as soon as peace is established in Mexico.

Mr. Richard K. Meade, consulting chemical engineer and cement expert of Baltimore, Md., was elected to membership in the Phi Beta Kappa Society at the recent commencement of the University of Virginia, in

recognition of his attainments in the field of chemical engineering and especially hydraulic cements. As the University of Virginia confers no honorary degrees election to this society is the highest gift the University may confer on its distinguished alumni.

Mr. Guy C. Riddell, formerly smelter superintendent for the A. S. & R. Co., at East Helena, Mont., has been retained to investigate the lead smelting practice of the same company.

Mr. Gilbert Rigg, formerly in charge of research work for the New Jersey Zinc Co., has been appointed to a consulting position in the zinc smelting department of the Broken Hill Associated Smelters Proprietary Co., Ltd., Port Pirie, South Australia.

Mr. O. C. Schaefer, formerly superintendent of the National Radium Institute of Denver, has accepted an appointment as superintendent with the Chemical Products Co. of Denver, manufacturers of molybdenum, vanadium and barium products.

Mr. E. Bryant Thornhill has accepted a position with the Metals Recovery Co., Ltd., Cobalt, Ontario, Canada.

Mr. Carl J. Trauerman, mining engineer and metallurgist, has resigned the position of mill superintendent of the August Mining Co., Landusky, Mont., and is inspecting the properties of the Beaver Creek Mines Co. of Zortman, Mont. After examining mines in the Kendall, Elliston and York districts of Montana he will return to his headquarters at Butte, Mont.

Prof. A. L. Van Hecke of the University of Louvain, Belgium, is in this country studying the latest developments in steel and iron. He attended the recent meeting of the American Society for Testing Materials at Atlantic City.

Mr. A. Van Zwaluwenburg is now chemist for the Nipissing Mines, Ltd., Cobalt, Ontario, having given up his position with Walter Harvey Weed in preparation of the Mines Handbook.

A number of changes have recently taken place in the U. S. Bureau of Mines. Mr. C. A. Wright, who has been in the Joplin district for some time, has been transferred to Salt Lake City. From the Denver office of the bureau, Mr. Alan Leighton has gone to the Goodrich Rubber Co., Akron, O.; Mr. J. C. Morgan has been transferred to Salt Lake City; Mr. H. A. Doerner has been engaged by the Chemical Products Co. of Denver, and Mr. C. F. Whittemore has accepted a place with the Schlesinger Radium Co. of Denver.

Mr. R. J. Weitlaner, formerly with the Midvale Steel Company, is now in charge of a Heroult electric steel furnace at the plant of the Hess Steel Corporation in Baltimore, Md.

Obituary

Lucius L. Wittich, mining news editor of the Joplin (Mo.) News Herald, died at Joplin on June 25, 1916. For many years his name had been prominently identified with the lead and zinc industry of Missouri and particularly of the Joplin district, through his contributions to the popular and technical press and his skill in gathering and presenting statistics on lead and zinc production. He had the latter feature well organized and the results were considered reliable and representative. As a leader in local mining news circles, his loss is keenly felt and his place difficult to fill.

Alvin R. Kenner, graduate mining engineer from the Colorado School of Mines in 1907, was found drowned in a lake near Grass Valley, Cal., on July 5. Mr. Kenner was superintendent of the Rio Plata Min-

ing Co. in Mexico and visiting in the States at the time of his death. He was an occasional contributor to the technical press and was favorably known among his engineering colleagues.

Industrial Notes

Fluorspar in 1915.—The year 1915 was a record year in the fluorspar industry in the United States, according to a Geological Survey Report by E. F. Buchard. The output of 136,941 short tons exceeded that of the next highest year 1912 by more than 20,000 tons, or nearly 18 per cent. The general average price of domestic fluorspar has declined steadily in the last four years, largely as a result of improvements in methods of milling and handling large quantities in the Illinois-Kentucky District, and this price was lower in 1915 than at any time in the last ten years.

Standard Methods of Gas Testing.—The second edition of this work has just been published by the Bureau of Standards as Circular No. 48. The first edition was compiled to fill the need for a publication which could be accepted as a standard guide to the methods of testing gas used for illuminating and heating purposes. The second edition is a revision of the first, embodying new suggestions and the results of work carried out by the Bureau. The different sections deal with the following subjects: location and general equipment of laboratory, measurement of gas, measurement of heating values, candlepower determination, determination of impurities, pressure records, meter testing, specific gravity, dew point and atmospheric humidity.

Rennerfelt Electric Furnaces.—Hamilton & Hansell, 17 Battery Place, New York, announce the sale of the following Rennerfelt furnaces:

One 2 3-ton, 150-kw. to the Tungsten Products Co., Boulder, Col., for making ferrotungsten. Two further furnaces, one 3 tons, one 6 tons, for making ferrotungsten. Not at liberty to name the party at this time, although the furnaces are for domestic use. One 3-ton, 225-kw. for making steel to the Samson Iron Works, Stockton, Cal. One 1 3-ton, 100-kw. for bronze to the Titanium Alloy Mfg. Co., Niagara Falls, N. Y. One 1 3-ton, 100-kw. for bronze to the Gerline Brass Foundry Co., Kalamazoo, Mich.

In addition to this, three additional furnaces were sold in Europe, making sixty-four Rennerfelt furnaces contracted for now in the world, fourteen of which are for the United States.

Dividends of German Companies.—The annual statements of the most prominent German companies for 1915 show that the number of companies announcing no dividends for the year was relatively small compared with the total number reviewed, according to a U. S. Consular report. It also appears that an excessive decrease in dividends was only declared in a minority of cases, and only by undertakings that were either insufficiently financed originally or were manufacturing articles of luxury and products intended for export. The porcelain and glass industries as well as the potash works, which generally exported more than half of their entire production, naturally had to declare greatly decreased dividends because the loss of exports could not be replaced in other ways. The cement factories, which were not in the best of condition in times of peace, have suffered greatly.

In general, decreased dividends were reported by the industrial lines not actively engaged in the manu-

facture of war supplies. The limitation of production in many industries has not only been caused by a decreased demand but by a lack of producing facilities. The industrial lines in which relatively high dividends were announced are principally mill products, chemicals, paper, coal, iron, steel and textile industries.

The D'Olier Centrifugal Pump & Machinery Co., Philadelphia, Pa., describes in the June issue of its bulletin wood screw type pumps for irrigation and drainage service, centrifugal pumps and multi-stage pumps. Descriptions of the D'Olier-Weston centrifugal pumps are also included.

Large Increase in Coke Production.—The coke production in the United States in 1915 was 41,581,150 short tons, an increase of 20 per cent over the 1914 production. Of this total, 34 per cent was by-product coke and the balance was made in bee-hive ovens. The increase over 1914 in the output of by-product coke was 25 per cent, and in bee-hive coke 18 per cent. The quantity of by-product coke made was the greatest yet recorded.

Lignite in South Dakota.—In Perkins and Harding Counties in South Dakota, it is estimated by United States Geological Survey that there are 1,000,000,000 tons of lignite. The estimate is given in Bulletin 627, just published. At present this lignite is mined for local domestic use and as fuel for steam plow equipments. Experiments made by the United States Geological Survey and later at the Bureau of Mines and the North Dakota School of Mines have proved that this lignite, on briquetting, makes a very superior fuel. When burned without briquetting in a producer-gas engine it is more efficient than the best coal when burned under boilers.

Dyestuff Industry Developing in Japan.—According to a representative of the Mitsui Mining Co., as published in Commerce Reports, all the by-products of the Government Iron Works, the Mitsui Mining Co., the Mitsu Bishi Co., the Tokyo Gas Co., the Osaka Gas Co. and other factories are being fully used. The supply of coal tar now exceeds 60,000 tons. In its distillation many big commercial interests are engaged. The foremost of these is the Nippon Dyestuff Co., which has a capital of 8,000,000 yen (\$3,988,000). It profits from Government protection under the law for the encouragement of chemical and dyestuff industries, although the concern is still far from actually being in operation. Gas companies in Osaka and Tokyo have also taken up the manufacture as a subsidiary branch, as they have a good supply of coal tar at their disposal. Aniline salt and induline are already marketed by the Tokyo Gas Co. The Mitsui Mining Co. has succeeded in producing a variety of dyes from the coal tar produced by its works at Miike. A month hence the company hopes to extend the list of its products so as to include additional derivatives of benzol, carbolic acid, salicylic acid and picric acid. There are also many minor enterprises engaged in this branch, including the Osaka Chemical Industry Co. and the Kobe Seikojo. These produce several artificial dyestuffs and contribute much to the rapid development of the important new industry in this country. There are still many difficulties to be overcome. In the first place the scarcity of auxiliary materials hampers the efforts of manufacturers. Sulphuric acid is obtainable, but there is said to be no stock of oleum in this country. Caustic soda and soda ash are also scarce. Unless these materials can be more freely supplied the development of the dyestuff industry will be seriously retarded. In the second place dye-

stuff producers are confronted with a grave problem in finding a market for by-products. The local demand is small. The success of dyestuff enterprises depends largely on the advantageous disposal of these by-products. Lastly, there is a pronounced technical difficulty to be overcome. As the enterprises are developed the equipment necessarily becomes more and more elaborate, and experts' difficulties in handling the problems are all the more enhanced.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

704,401, July 8, 1902, Julius Taluau of Philadelphia, Pa., assignor of one-half to Henry W. Scattergood of Philadelphia, Pa.

Relates to a method of framing glass suitable for making stained glass windows, and refers to an earlier application filed in 1895, serial number 572,318. In the present invention, a conducting support such as sheet lead, has placed upon it pieces of wax or other non-conducting adhesive which are of the same shape as the glass pieces, but are slightly smaller, so as to leave an edge around the under side of the glass pieces which are supported upon the smaller wax pieces. Spaces are also left between the several glass pieces. The assembled mass is now placed in the depositing vat, and metal deposited upon the lead sheet between the pieces of glass, and continued until it overlaps at the upper edges thereof, the deposit upon the lower side overlapping the bottom edges on account of the wax sheets having been cut smaller and providing the free edge above referred to. The united glass pieces are then suitably framed.

709,513, Sept. 23, 1902, Henry W. Scattergood of Philadelphia, Pa.

Relates to a method of framing glass or other materials, for making stained glass windows, mosaics, and the like, and consists in securing the glass pieces to a piece of tissue-paper, leaving spaces between the glass pieces, filling the spaces with a starch composition or the like which may be subsequently removed by washing, inclosing the entire object in a frame and filling the frame with sand or other easily removable packing and securing the sand in the frame by a removable cover. The frame with its contents is now inverted, and the tissue-paper removed; a coating of graphite or bronze powder is applied to the entire back of the glass pieces and starch filling, and conductors connected thereto. A second frame is then attached to the first and filled with wax. The entire mass is now inverted, the sand and starch filling removed, and then immersed in an electrolytic tank, deposition of metal being effected upon the graphite in the spaces between the glass pieces to the desired thickness so as to securely hold the glass. The spaces may be partly filled with metal filings if desired to reduce the quantity of electrodeposit required. The structure is now inverted, the wax backing and graphite removed, and the deposition of metal continued upon the metal seams between the pieces of glass until they are securely held on both sides of the assembled window.

Aqueous Bath, Cathodes Metalizing

7,821, Dec. 10, 1850, George Mathiot of Washington, D. C.

Relates to coating a cathode with a deposit which facilitates subsequent separation of an electrodeposited coating. For engraved metallic plates, etc., an electrode of silver is first deposited, this silver deposit is chemically cleaned, and is then treated with an alcoholic solution of iodine which is then quickly drained off, and the plate exposed to the light for one or more hours, when it acquires a "leaden" appearance. It is now immersed in the electrolyte and the deposit proceeded with by the usual methods. When completed the deposit is readily separated from the cathode plate. For large cathodes, of 10 sq. ft. or more surface, one grain of iodine is dissolved in 20,000 grains of alcohol; for smaller plates, stronger solutions may be used.

23,633, April 12, 1859, John W. Wilcox of West Roxbury, Mass.

Relates to making rolls for printing, paper-making, etc., and consists in covering an iron or other metal roll with a strip of copper wound as a helix, the joints between the turns of the strip soldered, and the strip itself may be soldered throughout to the roll. The completely covered roll is then turned or ground perfectly true, and electroplated with a thick coat of copper. It is then ready for use.

Book Reviews

The Molecular Volumes of Liquid Chemical Compounds. By Gervaise Le Bas, B. Sc. Octavo (15 x 22 cm.), 272 pages, 9 illustrations; price, \$2.25. London and New York: Longmans, Green & Co.

This treatise is for advanced students of chemistry, and is intended to elaborate the theory of molecular volumes of Kopp in the light of modern researches. The author retains Kopp's conception of molecular and atomic volumes and of the additive principle in this connection, but adds to these several modifications, such as using several atomic volumes for oxygen and nitrogen in different types of compounds. By also revising the values of the atomic volumes of carbon and hydrogen, used by Kopp, many constitutive properties of compounds are thus revealed and a fairly consistent theory of molecular structure built up. The whole is a report of progress, worth careful study by all interested in physical chemistry, but the conclusions lack finality—which holds out good promise of still further progress.

Steel and Its Heat Treatment. By Denison K. Bullens, Consulting Metallurgist. Octavo (14 x 22 cm.), 431 pages, 223 illustrations; price, \$3.75. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd.

This is a good treatise on annealing, hardening, tempering, toughening, and case-hardening of carbon, nickel, chromium, chromium-nickel, vanadium, manganese, tungsten and other alloy steels, together with chapters on pyrometers, critical range determinations, and mechanical testing. We find it a very readable and interesting book, with a mass of well-arranged and useful information. It is, however, far from complete, and may disappoint because of its omissions, such as the special treatment of high-tungsten steel for magnets and high-speed tools, the meager description of heating baths and of electric heating furnaces for automatic heat treatment. We protest, also, against "chrome" being generally used instead of "chromium" throughout the book—a point on which the printed treatise should rectify current workshop carelessness. With some such additions and corrections as above mentioned the book could be made considerably better.